EXHIBIT A

US007944935B2

(12) **United States Patent**
Bucknell et al.

(10) **Patent No.: US 7,944,935 B2**
(45) **Date of Patent: May 17, 2011**

(54) **METHOD FOR PRIORITY BASED QUEUING AND ASSEMBLING OF PACKETS**

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(73) Assignee: **Koninklijke Philips Electronics N.V.**, Eindhoven (NL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 520 days.

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H04L 12/28 (2006.01)
H04L 12/54 (2006.01)
H04L 12/56 (2006.01)

(52) **U.S. Cl.** **370/412**; 340/417; 340/429

(58) **Field of Classification Search** 370/229, 370/412, 417, 429
See application file for complete search history.

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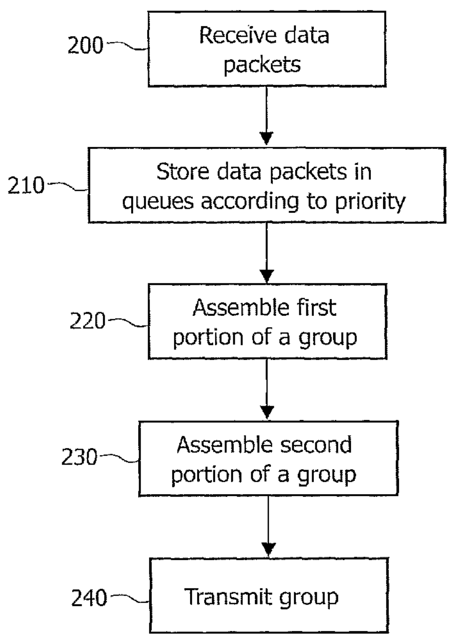
(57) **ABSTRACT**

Data packets having different assigned priorities are multiplexed by operating a queue for each different priority of data packet and assembling groups (**80**) of the data packets for transmission. Each group has two portions. A first portion (**90**) of the group is populated with data packets selected from one or more of the queues according to a first rule and a second portion (**95**) of the group is populated with data packets selected from one or more of the queues according to a second rule. Preferably the first portion contains data packets having the highest priority, and the second portion contains a selection of the data packets having a lower a priority. Selection of data packets for the second portion may depend on criteria such as delay experienced and queue length. The size of the first and second portions may be adapted according to delay experienced and queue length.

18 Claims, 2 Drawing Sheets



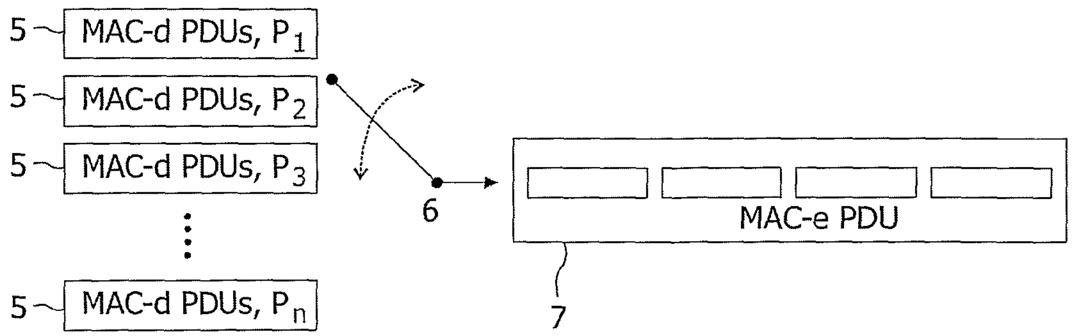


FIG. 1 PRIOR ART

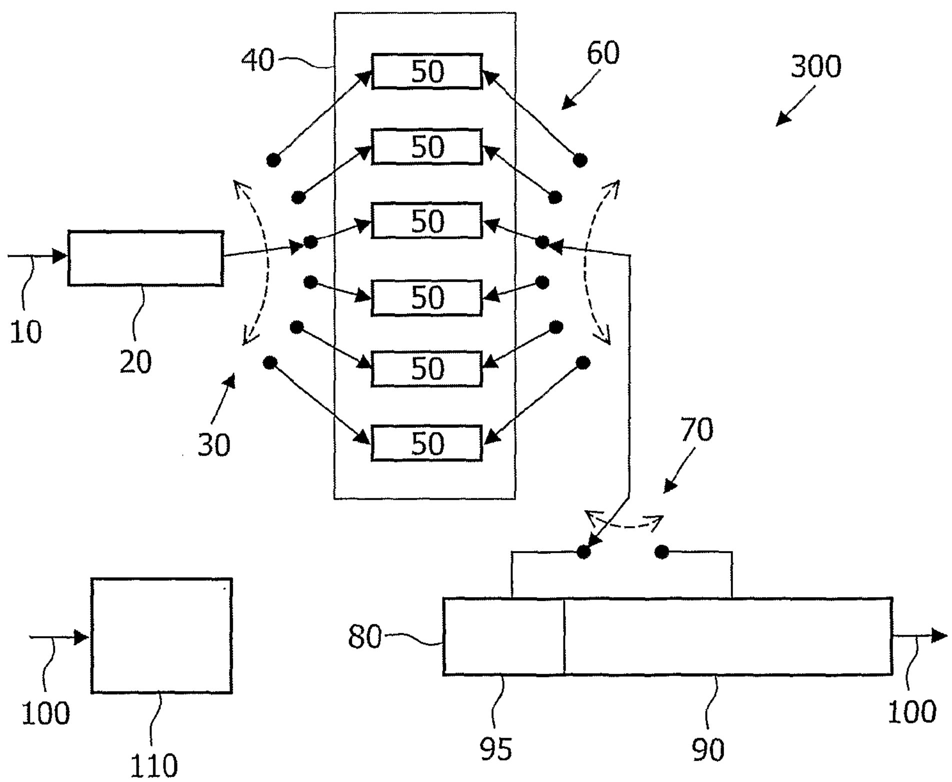


FIG. 2

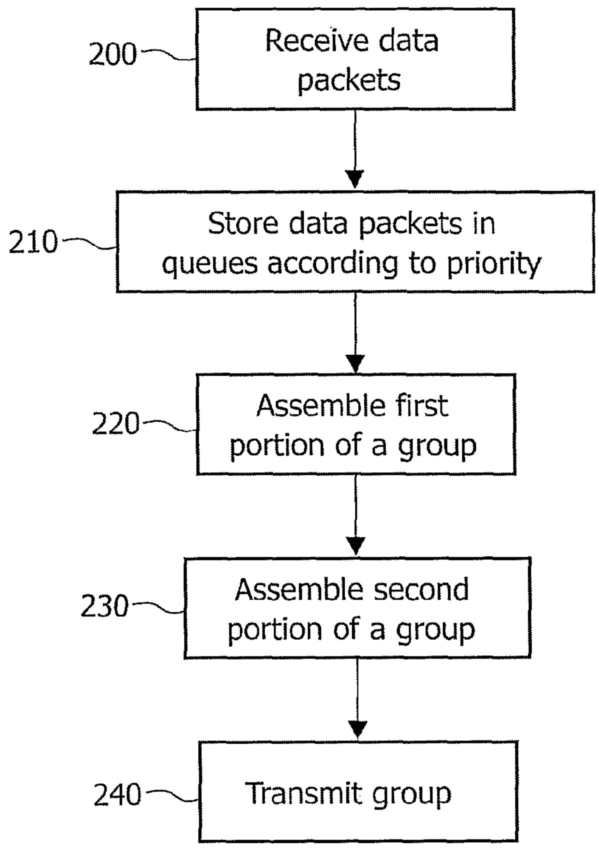

200
Receive data packets
210
Store data packets in queues according to priority
220
Assemble first portion of a group
230
Assemble second portion of a group
240
Transmit group

FIG. 3

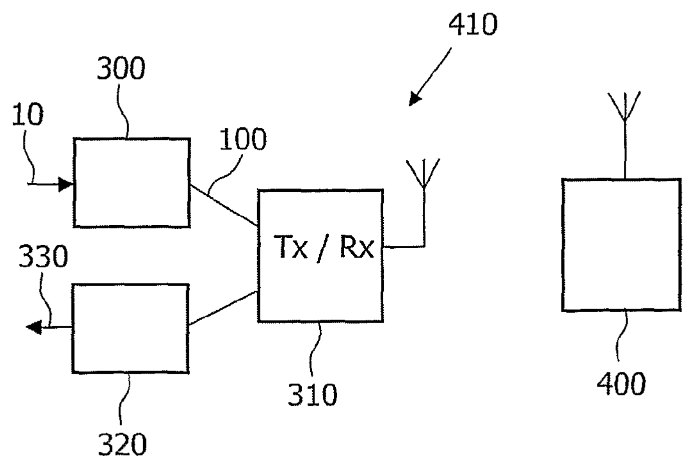

410
300
10
100
Tx / Rx
330
310
400
320

FIG. 4

METHOD FOR PRIORITY BASED QUEUING AND ASSEMBLING OF PACKETS

The invention relates to a method of multiplexing data packets, to a multiplexing apparatus for multiplexing data packets, to a communication terminal comprising the multiplexing apparatus, and to a communication system comprising the communication terminal. The invention has application in, for example but not exclusively, mobile communication systems such as the Universal Mobile Telecommunication System (UMTS).

There is a requirement in communication systems to multiplex data packets having different priorities. For example, in UMTS for an Enhanced Uplink Data Channel (E-DCH), at the Medium Access Control (MAC) layer data packets, referred to as MAC-d Protocol Data Units or MAC-d PDUs, are grouped together for transmission to form larger, enhanced PDUs termed MAC-e PDUs. When there is a continuous supply of MAC-d PDUs having the highest priority, the MAC-e PDUs can be filled with these high priority MAC-d PDUs, but when there are fewer high priority MAC-d PDUs to be transmitted, any spare capacity in the MAC-e PDUs can be used to transmit waiting MAC-d PDUs having a lower priority. In this way, a MAC-e PDU can accommodate a combination of different priorities of MAC-d PDU.

In UMTS, the process of multiplexing of MAC-d PDUs into MAC-e PDUs is responsible for ensuring that MAC-d flow priorities are taken into account in an appropriate way. In the simplest case, this multiplexing could simply follow the priorities directly. An example illustrated in FIG. **1** shows queues **5** of MAC-d PDUs having different priorities $P_1 \ldots P_n$, with the priorities decreasing from P_1 through to P_n, being multiplexed by a selector switch **6** onto a MAC-e PDU **7**. The MAC-e PDU can accommodate four MAC-d PDUs, and is populated with the MAC-d PDUs having the highest priority available. In this simple scheme if we have continuous high-priority MAC-d PDUs arriving for transmission, then the transmission of simultaneously-arriving lower-priority MAC-d PDUs will be delayed. Strictly priority-based multiplexing of MAC-d PDUs into the MAC-e PDUs will not always lead to the optimal filling of the MAC-e PDUs and would be too inflexible to satisfy all QoS (Quality of Service) requirements for PDUs, such as delay requirements and bit rate requirements. For example, queues containing low priority PDUs may experience starvation, being starved of opportunities to transmit their PDUs.

An object of the invention is to enable flexible and efficient multiplexing of data packets.

According to a first aspect of the invention there is provided a method of multiplexing data packets having different assigned priorities, comprising: receiving data packets; operating a queue for each different priority of data packet; assembling a group of the data packets wherein a first portion of the group is populated with data packets selected from one or more of the queues according to a first rule and a second portion of the group is populated with data packets selected from one or more of the queues according to a second rule; and transmitting the group.

The invention provides flexibility for appropriate handling of priorities, guaranteed bit-rates and starvation scenarios by dividing a data packet, such as a MAC-e PDU, that is large enough to accommodate a plurality of smaller data packets, such as MAC-d PDUs, into at least two portions and enabling different multiplexing rules to be used for the different portions. In this way, a combination of data packets having different priorities may be transmitted.

Preferably, according to the first rule, data packets are selected from the queue containing the highest priority of the data packets. This ensures that the highest priority data packets are assigned a regular portion of the capacity.

Preferably, according to the second rule, data packets are selected from one or more of the queues containing data packets having a lower priority than the highest priority. This ensures that the lower priority data packets are assigned some capacity.

In one embodiment, according to the second rule, data packets are selected from any queue, except at least the highest priority queue, for which the data packets have experienced a delay longer than a threshold delay. The threshold delay may be the same or different for the queues. This approach can assist compliance with a QoS delay requirement.

In one embodiment, according to the second rule, data packets are selected from any queue which has more data awaiting transmission than a threshold amount of data, except at least the highest priority queue. This approach can reduce the likelihood of buffer overrun in which a queue length exceeds the available buffer size.

In one embodiment, the sizes of the first and second portions of the group of data packets transmitted is adapted according to the prevailing mix of priorities of the data packets, or according to the amount of data in the queues, or according to the delay experienced by data in each queue relative to a delay criterion for the respective queue. This approach can enable efficient use of transmission capacity and can assist compliance with a QoS requirement.

According to a second aspect of the invention there is provided a multiplexing apparatus for multiplexing data packets having different assigned priorities, comprising means for receiving data packets, means for operating a queue for each different priority of data packet, means for assembling a group of the data packets wherein a first portion of the group is populated with data packets by selecting data packets from one or more of the queues according to a first rule and a second portion of the group is populated with data packets by selecting data packets from one or more of the queues according to a second rule, and means for transmitting the group.

According to a third aspect of the invention there is provided a communication terminal comprising the multiplexing apparatus in accordance with the second aspect of the invention.

According to a fourth aspect of the invention there is provided a communication system comprising, for transmitting data packets, a first communication terminal in accordance with the second aspect of the invention, and a second communication terminal for receiving the data packets.

The invention will now be described, by way of example, with reference to the accompanying drawings wherein;

FIG. **1** is a schematic diagram illustrating a prior art method of MAC-d multiplexing;

FIG. **2** is a multiplexing apparatus in accordance with the invention;

FIG. **3** is a flow chart illustrating a further method of multiplexing in accordance with the invention; and

FIG. **4** is a communication system in accordance with the invention.

Referring to FIG. **2**, there is illustrated an apparatus for multiplexing **300**, hereafter referred to as a multiplexing apparatus **300**. There is an input **10** for receiving data packets. Coupled to the input **10** is an input buffer **20**, such as a random access memory, for storing the received data packets. There is a bank **40** of a plurality of queue stores **50** for containing queues and which may comprise a storage medium such as

random access memory. The input buffer **20** is coupled to the bank **40** by means of a first routing means **30**, such as a switch or a functional equivalent, for routing each data packet from the input buffer **20** to one of the queue stores **50** according to a priority assigned to each data packet. The priority may be assigned to each data packet prior to reception of the data packet, or may be assigned by a control means **110**. Alternatively, the packets may be routed to the queue stores **50** according to their respective MAC-d flows, with each flow having an associated priority; this approach may be used if for example the flow priorities are changed dynamically. There is an output buffer **80**, such as a random access memory, for storing the data packets prior to transmission on an output **100**. The output buffer **80** comprises a first portion **90** and a second portion **95**. The first portion **90** and the second portion can each accommodate at least one data packet. Data packets are selected for transfer from the queue stores **50** to the output buffer **80** by means of a second routing means **60**, such as a switch or a functional equivalent, and are transferred into the first portion **90** or the second portion **95** by means of a switch **70**. The first and second routing switches **30**, **60** and the switch **70** are controlled by a control means **110**, such as a microprocessor. The control means **110** controls the routing of the data packets to the output buffer **80** according to a predetermined criterion. The control means **110** may also control the sizes of the first and second portions **90**, **95**.

The control means **110** may be adapted to populate the first portion **90** with data packets from the queue store **50** containing the highest priority data packets.

The control means **110** may be adapted to populate the second portion **95** with data packets from one or more of the queue stores **50** containing data packets of a lower priority than the highest priority. The lower priority data packets selected to populate the second portion **95** may be those which have experienced a delay longer than a predetermined delay threshold, or those that have experienced the longest delay. The predetermined delay threshold may be different or the same for each of the queue stores **50**. The lower priority data packets selected to populate the second portion **95** may be those in a queue store **50** which contains a number of data packets above a predetermined occupancy threshold. The predetermined occupancy threshold may be different or the same for each of the queue stores **50**. The selection of data packets to populate the second portion **95** need not be in order of priority.

The control means **110** may adapt the size of the first portion **90** and the second portion **95** according to the prevailing mix of priorities of the data packets stored in the bank **40**, or according to the amount of data packets stored in the queue stores **50**, or according to the delay experienced by data packets in each queue store **50** relative to a delay criterion for the respective queue, or according to a received signal indicative of a mix of first and second portions. In the latter case, the mix may comprise, for example, an indication of relative proportions or absolute sizes.

Referring to FIG. **3**, the illustrated method of multiplexing commences at step **200** where some data packets are received by the multiplexing apparatus **300**. They may be received with priorities already assigned to them, or priorities may be assigned after receipt. At step **210** the data packets are stored into the set of queue stores **50**, one queue store for each priority level $P_1 \ldots P_n$. One way of identifying which queue store **50** a data packet is stored in is by a label signifying the packet's priority level. At step **220** a first portion **90** of a group of data packets is assembled from data packets having the highest priority of the stored data packets. At step **230** a second portion **95** of a group of data packets is assembled

from data packets having a lower priority, or lower priorities. At step **240** the assembled group comprising the first portion **90** and second portion **95** is transmitted. The process is repeated for further data packets.

Some examples are given below of how the data packets may be selected from the queues in the queue stores **50** to populate the group of data packets assembled in the first portion **90** and second portion **95** of the output buffer **80**. In general we can assume that the resources available for the first portion **90** and the second portion **95** are both known before the multiplexing operation is carried out, for example in terms of the number of PDU's which can be transmitted. In the case that the resources are not known exactly in advance, for example if the total available resource depends in any way on the outcome of the multiplexing, it may be necessary to consider the outcome of the multiplexing for a number of possible resource allocations and then select one of them.

1) Strict priority based selection: In this case each MAC-d flow is assigned a priority. Then for the first selection, data packets are taken from the queue having the highest priority until the resource available for the first portion **90** is filled. If this queue becomes empty, data packets are taken from the queue with the next highest priority and so on. For the second portion **95** the same procedure is carried out, but for a subset of the queues. Suitable selection of the subset can enable the multiplexing apparatus **300** to avoid starvation of particular queues, for example to enable a delay criterion to be met.
2) Fair selection for the second portion: In this case the second portion **95** is populated by taking one data packet in turn from each of the subset of queues, excluding the highest priority queue. To maximise fairness, especially when a large number of queues are present, the last selected queue may be remembered for use in subsequent multiplexing operations.
3) As a variation on 2), if the resource available for the first portion **90** is not fully used, then the unused resource can be made available for the second portion **95**.
4) As a further variation on 2), the second portion **95** can be populated before the first portion **90**. This may allow some flexibility in regard to which queues make use of which of the portions.
5) The first and second portions **90**, **95** could be populated from different subsets of the queues.
6) The priorities can modified in a dynamic way, for example in response to commands or information received by the multiplexing apparatus **300**. Such modification can be applied to either or both of the first and second portions **90**, **95**. For example, if the transmission delay of a particular queue increases above a particular threshold, the priority of that queue may be temporarily increased in order to enable data from that queue to use a different one of the portions.
7) One or both selections for the first and second portions **90**, **95** can be based on the amount of data in the respective queues, for example assigning highest priority to the queue with most data.
8) Length of queue can be used to arbitrate between queues of equal priority, for example by selecting from the longest queue.
9) One or both selections for the first and second portions **90**, **95** can be modified to take into account the length of queue, for example by preferentially selecting from queues exceeding a certain length.
10) The selection can be based on the QoS currently achieved for a particular data flow. For example, data can be preferentially selected from a queue where the average or worst case delay is exceeding a QoS requirement.

11) The size of the resource for each portion **90**, **95** can be adapted to take into account the amount of data in each queue, for example dividing the resource in a way which is proportional to the amount of data in the relevant queues.

12) The size of the resource for each portion **90**, **95** can be adapted to take into account the QoS requirements of the data in each queue, for example dividing the resource in a way which gives more resource to the selection which has the strictest QoS requirements.

13) The size of the resource for each portion **90**, **95** can be adapted to take into account the QoS currently being achieved for the data in each queue, for example dividing the resource in a way which gives more resource to the portion **90**, **95** which is not meeting, or is furthest from meeting, any delay requirements.

Criteria other than priority may be used to determine which queue store **50** each data packet is assigned to, for example, type of data or a quality of service requirement of the data packet. In this case the data packets do not need to have an explicit priority assigned to them, instead data type functioning as an equivalent characteristic to priority, or instead the data type defining an implicit priority. Similarly, criteria other than priority may be used to determine which of the first and second portions **90**, **95** each data packet may be assigned to.

Referring to FIG. **4**, there is illustrated a communication system comprising a communication terminal **410** for transmitting data and a communication terminal **400** for receiving the transmitted data. The communication terminal **410** for transmitting data comprises the apparatus for multiplexing **300** as described above with reference to FIG. **2** coupled to a transceiver **310** for transmitting data and receiving acknowledgements, and a processor **320** for processing the received acknowledgements and delivering a signal on an output **330**.

The multiplexing apparatus **300** may be adapted to receive on an input **100**, for example via the transceiver **310**, a signal indicative of a mix of first and second portions **90**, **95**, and may be adapted to set the size of the first and second portions **90**, **95** in response to the signal. The multiplexing apparatus **300** may be adapted to receive on an input **100**, for example via the transceiver **310**, a signal indicative of how the data packets may be selected from the queue stores **50** to populate the group of data packets assembled in the first portion **90** and second portion **95** of the output buffer **80**, and to adapt its operation in accordance with the signal. Such signals may be transmitted by the communication terminal **400** or another source.

Although the invention has been described with the output buffer **80** having a first portion **90** and a second portion **95**, the use of additional portions is not precluded, and the techniques described may be applied to populating the additional portions.

Although the invention has been described with reference to UMTS, its use is not limited to UMTS, and it can be used in other communication systems, particularly in mobile communication systems. The use of the invention is not limited to wireless communication systems.

In the present specification and claims the word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. Further, the word "comprising" does not exclude the presence of other elements or steps than those listed.

The inclusion of reference signs in parentheses in the claims is intended to aid understanding and is not intended to be limiting.

From reading the present disclosure, other modifications will be apparent to persons skilled in the art. Such modifications may involve other features which are already known in the art of data communication which may be used instead of or in addition to features already described herein.

The invention claimed is:

1. A microprocessor-based method of multiplexing data packets having different assigned priorities, comprising:

receiving data packets;

operating a queue for each different priority of data packet;

assembling a group of the data packets wherein a first portion of the group is populated with data packets selected from one or more of the queues according to a first rule and a second portion of the group is populated with data packets selected from one or more of the queues according to a second rule; and

transmitting the group, wherein the size of the first and second portions is adapted according to the delay experienced by data in each queue relative to a delay criterion for the respective queue.

2. The method of multiplexing as claimed in claim **1** wherein according to the first rule data packets are selected from the queue containing the highest priority of the data packets.

3. The method of multiplexing as claimed in claim **1**, wherein according to the second rule data packets are selected from one or more of the queues containing data packets having a lower priority than the highest priority.

4. The method of multiplexing as claimed in claim **1**, wherein according to the second rule data packets are selected from any queue, except at least the highest priority queue, for which the data packets have experienced a delay longer than a threshold delay.

5. The method of multiplexing as claimed in claim **1**, wherein according to the second rule data packets are selected from any queue which has more data awaiting transmission than a threshold amount of data, except at least the highest priority queue.

6. The method of multiplexing as claimed in claim **1**, comprising adapting the size of the first and second portions according to the prevailing mix of priorities of the data packets.

7. The method of multiplexing as claimed in claim **1**, comprising adapting the size of the first and second portions according to the amount of data in the queues.

8. The method of multiplexing as claimed in claim **1**, comprising receiving a signal indicative of a mix of first and second portions and adapting the size of the first and second portions in response to the signal.

9. A multiplexing apparatus for multiplexing data packets having different assigned priorities, comprising:

means for receiving data packets;

means for operating a queue store for each different priority of data packet;

means for assembling a group of the data packets wherein a first portion of the group is populated with data packets by selecting data packets from one or more of the queue stores according to a first rule and a second portion of the group is populated with data packets by selecting data packets from one or more of the queue stores according to a second rule; and

means for transmitting the group, wherein the size of the first and second portions is adapted according to the delay experienced by data in each queue relative to a delay criterion for the respective queue.

10. The multiplexing apparatus as claimed in claim **9** wherein according to the first rule data packets are selected from the queue store containing the highest priority of the data packets.

11. The multiplexing apparatus as claimed in claim **9**, wherein according to the second rule data packets are selected from one or more of the queue stores containing data packets having a lower priority than the highest priority.

12. The multiplexing apparatus as claimed in claim **9**, wherein according to the second rule data packets are selected from any queue store, except at least the highest priority queue store, for which the data packets have experienced a delay longer than a threshold delay.

13. The multiplexing apparatus as claimed in claim **9**, wherein according to the second rule data packets are selected from any queue store which has more data awaiting transmission than a threshold amount of data, except at least the highest priority queue store.

14. The multiplexing apparatus as claimed in claim **9**, comprising means for adapting the size of the first and second portions according to the prevailing mix of priorities of the data packets.

15. The multiplexing apparatus as claimed in claim **9**, comprising means for adapting the size of the first and second portions according to the amount of data in the queue stores.

16. The multiplexing apparatus as claimed in claim **9**, comprising means for receiving a signal indicative of a mix of first and second portions and means for adapting the size of the first and second portions in response to the signal.

17. A communication terminal comprising the multiplexing apparatus as claimed in claim **9**.

18. A communication system comprising a first communication terminal as claimed in claim **17** for transmitting data packets, and a second communication terminal for receiving the data packets.

* * * * *

EXHIBIT B

US007554943B2

(12) **United States Patent**
Moulsley et al.

(10) **Patent No.: US 7,554,943 B2**
(45) **Date of Patent: Jun. 30, 2009**

(54) **RADIO COMMUNICATION SYSTEM**

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(73) Assignee: **Koninklijke Philips Electronics N.V.**, Eindhoven (NL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 682 days.

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(86) PCT No.: **PCT/IB03/00225**

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(2), (4) Date: **Aug. 3, 2004**

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PCT Pub. Date: **Aug. 14, 2003**

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Feb. 12, 2002 (GB) 0203263.9

(51) **Int. Cl.**
H04W 4/00 (2006.01)
(52) **U.S. Cl.** **370/329**; 370/343
(58) **Field of Classification Search** 370/329, 370/330, 243, 343, 341, 468, 503
See application file for complete search history.

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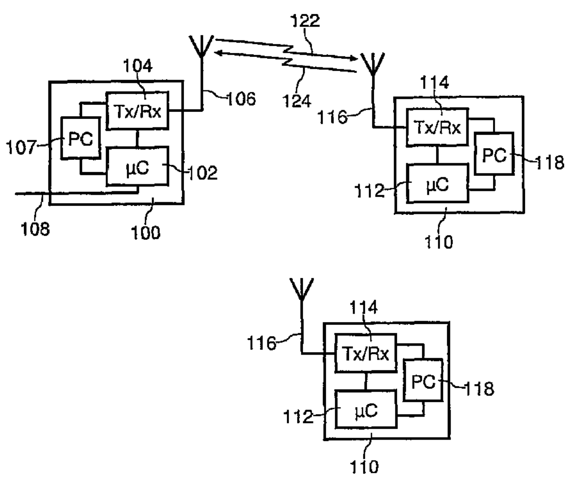
Primary Examiner—Kwang B Yao
Assistant Examiner—Andrew Lai

(57) **ABSTRACT**

In a radio communication system having a data channel for the transmission of data packets from a primary station to a secondary station, a plurality of downlink control channels are used to signal information relating to packet transmission. A problem with this scheme is that with a fixed control channel allocation system throughput (T) for a given offered load (O) can be significantly reduced in a worst case scenario (for example two secondary stations using the same control channel). One solution uses an indicator signal to inform a secondary station of the control channel it should receive, but this adds significant complexity to the system. The present invention provides a simpler scheme having similar benefits by shuffling the allocation of control channels to secondary stations, according to a defined sequence for each secondary station, thereby avoiding the worst case scenario.

17 Claims, 1 Drawing Sheet



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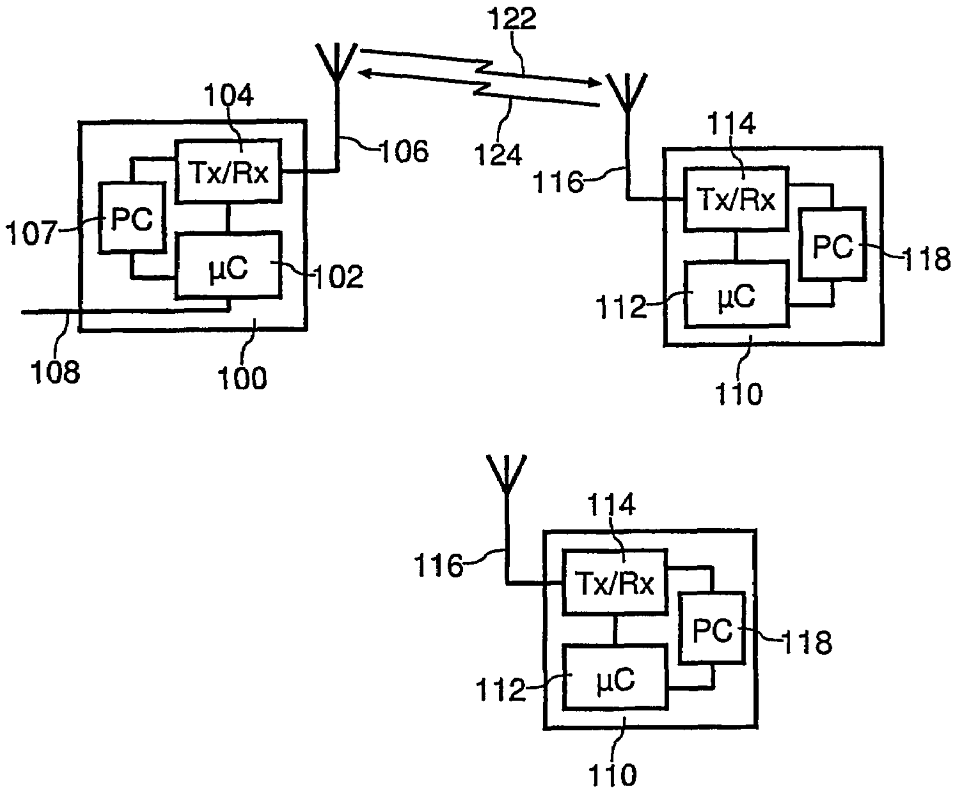
122
124
104
Tx/Rx
106
PC
107
μC
102
108
100
114
116
Tx/Rx
PC
118
112
μC
110
114
116
Tx/Rx
PC
118
112
μC
110

FIG. 1

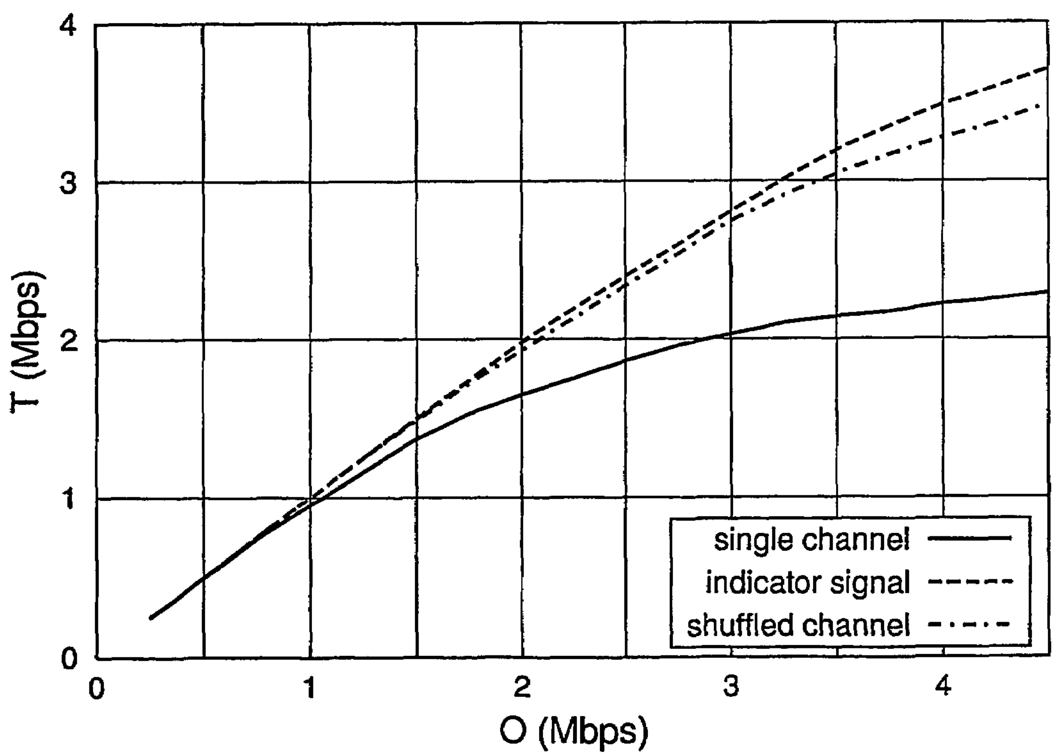
T (Mbps)
4
3
2
1
0
0
1
2
3
4
O (Mbps)
single channel
indicator signal
shuffled channel

FIG. 2

RADIO COMMUNICATION SYSTEM

TECHNICAL FIELD

The present invention relates to a radio communication system and further relates to primary and secondary stations for use in such a system and to a method of operating such a system. While the present specification describes a system with particular reference to the Universal Mobile Telecommunication System (UMTS), it is to be understood that such techniques are equally applicable to use in other mobile radio systems.

BACKGROUND ART

There is a growing demand in the mobile communication area for a system having the ability to download large blocks of data to a Mobile Station (MS) on demand at a reasonable rate. Such data could for example be web pages from the Internet, possibly including video clips or similar. Typically a particular MS will only require such data intermittently, so fixed bandwidth dedicated links are not appropriate. To meet this requirement in UMTS, a High-Speed Downlink Packet Access (HSDPA) scheme is being developed which may facilitate transfer of packet data to a mobile station at up to 4 Mbps.

A particular problem with the design of the HSDPA scheme is the mechanism for informing a MS of the presence of a data packet for it to receive and providing information relating to the packet (typically including details of the particular transmission scheme employed, for example spreading code, modulation scheme and coding scheme). As currently proposed, this information is signalled on one of four available downlink control channels, distinguished by their spreading codes. The MS is instructed to decode one of the control channels by a two-bit indicator signal which is transmitted on a low data rate dedicated downlink channel (the signal being inserted by puncturing). The MS then monitors the same control channel for subsequent packets in a burst.

This scheme conveniently supports the scheduling of up to four packets to different MSs in the same time interval. Use of the indicator signal is intended to reduce the complexity of the MS and its power consumption, as the MS only needs to monitor the dedicated downlink channel for the indicator signal instead of having to receive continuously all four control channels. However, there are significant drawbacks with the use of the indicator signal. One drawback is that an additional slot format is required for the dedicated downlink channel (to accommodate the extra signal), which adds complexity. Another drawback is that the transmission power required for the indicator signal can be relatively high to ensure reliable reception of the signal even at the edge of a cell.

One solution which avoids the use of an indicator signal is for each MS to be allocated one of the four control channels, which it then continuously monitors. However, if more than one MS is allocated the same control channel the flexibility of packet scheduling is restricted. Another solution is the provision of one control channel for each MS; however, the potentially large number of channels required could use up excessive system resources.

DISCLOSURE OF INVENTION

An object of the present invention is to provide an improved arrangement which does not require an indicator signal or provision of a large number of control channels.

According to a first aspect of the present invention there is provided a radio communication system having a data channel for the transmission of data packets from a primary station to a secondary station and a plurality of control channels for signalling of control information relating to the data packets from the primary station to the secondary station, wherein the primary station comprises means for allocating one of the control channels to the secondary station and means for changing the allocated control channel according to a defined sequence, and the secondary station comprises means for monitoring the currently allocated control channel to determine information about packet transmissions.

By changing the control channel allocation, system performance is greatly enhanced under worst-case conditions without the need for an indicator signal, which introduces significant extra complexity. The defined sequence may repeat regularly, for example once per frame, and may use as a timing reference a common downlink channel, for example a synchronisation channel in UMTS.

When control channels are allocated to a plurality of secondary stations, their respective defined sequences are preferably all different (provided the number of secondary stations is not too great), and some (but not necessarily all) of the sequences may include only a single control channel.

According to a second aspect of the present invention there is provided a primary station for use in a radio communication system having a data channel for the transmission of data packets from the primary station to a secondary station and a plurality of control channels for signalling of control information relating to the data packets from the primary station to the secondary station, wherein means are provided for allocating one of the control channels to the secondary station and for changing the allocated control channel according to a defined sequence.

According to a third aspect of the present invention there is provided a secondary station for use in a radio communication system having a data channel for the transmission of data packets from a primary station to the secondary station and a plurality of control channels for signalling of control information relating to the data packets from the primary station to the secondary station, wherein means are provided for determining which of the control channels is allocated to the secondary station, the allocated control channel being changed according to a defined sequence, and for monitoring the currently allocated control channel to determine information about packet transmissions.

According to a fourth aspect of the present invention there is provided a method of operating a radio communication system having a data channel for the transmission of data packets from a primary station to a secondary station and a plurality of control channels for signalling of control information relating to the data packets from the primary station to the secondary station, the method comprising the primary station allocating one of the control channels to the secondary station and changing the allocated control channel according to a defined sequence, and the secondary station monitoring the currently allocated control channel to determine information about packet transmissions.

BRIEF DESCRIPTION OF DRAWINGS

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

FIG. **1** is a block schematic diagram of a radio communication system; and

FIG. **2** is a graph of worst-case system throughput T in millions of bits per second (Mbps) against offered load O in Mbps for various control channel schemes.

MODES FOR CARRYING OUT THE INVENTION

Referring to FIG. **1**, a radio communication system comprises a primary station (BS) **100** and a plurality of secondary stations (MS) **110**. The BS **100** comprises a microcontroller (μC) **102**, transceiver means (Tx/Rx) **104** connected to antenna means **106**, power control means (PC) **107** for altering the transmitted power level, and connection means **108** for connection to the PSTN or other suitable network. Each MS **110** comprises a microcontroller (μC) **112**, transceiver means (Tx/Rx) **114** connected to antenna means **116**, and power control means (PC) **118** for altering the transmitted power level. Communication from BS **100** to MS **110** takes place on a downlink channel **122**, while communication from MS **110** to BS **100** takes place on an uplink channel **124**.

The general characteristics of the UMTS HSDPA were outlined above and are summarised here for clarity:

- There are (low data rate) dedicated uplink **124** and downlink **122** channels between a BS **100** and each MS **110** in its cell.
- A specific downlink channel 122 is used for high-speed transmission of data packets. This channel is subdivided into Transmission Time Intervals (TTIs), where each TTI is the time taken for transmission of a data packet. In UMTS the duration of a TTI is 2 ms, and this time period is also identified as a sub-frame (there being three time slots in a sub-frame, and hence 5 time slots in a 10 ms frame).
- Up to four downlink control channels are provided, distinguished by their spreading codes and each relating to transmission parameters of a data packet. Hence, up to four data packets can be transmitted simultaneously per TTI.

  The requirement for being able to schedule four data packets to different stations **110** in the same TTI is to allow high system throughput to be achieved in a cell in which some stations **110** do not have the ability to receive all of the HSDPA downlink resource. For example, some stations **110** may be able to receive only 5 spreading codes when there are up to 15 available.
- A mechanism is provided for indicating to a particular MS **110** that it is scheduled to receive a data packet and for indicating which control channel it should listen to in order to determine how to receive the packet.

As described above, one possible mechanism is the transmission of an indicator signal on the dedicated downlink channel **122** to inform a MS **110** of the transmission of a data packet. However, this mechanism has a number of problems.

As an alternative each MS **110** could be allocated one of the control channels to monitor, thereby avoiding the need for an indicator signal. However, if more than one MS **110** is allocated to a particular control channel the flexibility of packet scheduling is restricted. For example, consider two mobile stations **110**, each with data to be sent but both allocated the same control channel. It would generally be desirable to send data simultaneously to both stations **110**. However as both stations are sharing a control channel, only one packet can be sent at a time. Given that packet transmission is often bursty in nature, this situation is likely to continue for several TTIs and the system throughput could be only 50% of the maximum. Greater scheduling flexibility could be introduced by requiring each MS **110** to monitor two control channels, but at the cost of increased MS power consumption.

In a system made in accordance with the present invention, this problem is addressed by shuffling the allocation of control channels from one TTI to the next. Hence, if two stations **110** share a control channel in one TTI they will have different ones in the next TTI. If such a scheme is applied to the example above of two active stations **110**, then a well-designed shuffling scheme should be able to reduce the probability of an "allocation collision" to $1/N_{con}$, where N_{con} is the total number of control channels (four in the above examples). The maximum loss in throughput would then be $0.5/N_{con}$, or 12.5% with $N_{con}=4$ (compared to 50% without shuffling).

Some examples of how shuffling may be done will now be presented, although the schemes themselves are not necessarily optimal.

First consider the case of two control channels and four stations **110**. The allocation of control channels to each station (0 to 3) for each TTI (0 to 4) in a 10 ms frame is:

	TTI				
station	0	1	2	3	4
0	0	0	0	0	0
1	1	1	1	1	1
2	0	1	0	1	0
3	1	0	1	0	1

This scheme could either repeat in the next frame or be made into a longer cycle.

Next, consider an extension of the above scheme to the case of two control channels and six stations **110**:

	TTI				
station	0	1	2	3	4
0	0	0	0	0	0
1	1	1	1	1	1
2	0	1	0	1	0
3	1	0	1	0	1
4	0	0	1	1	0
5	1	1	0	0	1

As a third example, consider a system with four control channels and twelve stations **110**:

	TTI				
station	0	1	2	3	4
0	0	0	0	0	0
1	1	1	1	1	1
2	2	2	2	2	2
3	3	3	3	3	3
4	0	1	2	3	0
5	1	2	3	0	1
6	2	3	0	1	2
7	3	0	1	2	3
8	0	3	2	1	0
9	1	0	3	2	1
10	2	1	0	3	2
11	3	2	1	0	3

It may not be required to have a unique shuffling pattern for each MS **110**. In this case it seems preferable to take the

station number as a shuffling pattern identifier, and to assign stations **110** to each pattern in ascending sequence. Hence, for small numbers of stations **110** all (or most) of them will have a constant control channel allocation. Although convenient, it is clearly not a requirement of the present invention that any of the shuffling patterns relate to a constant control channel allocation.

The shuffling pattern of the third example can be represented as

$$n_{CCH}=[(a\times n_{TTI})+b] \bmod N_{CCH}$$

where: n_{CCH} is the number of the control channel to be used; N_{CCH} is the total number of control channels available; n_{TTI} is the number of the TTI in the frame; a is a parameter taking values 0, 1 or 3; and b is a parameter taking values 0, 1, 2 or 3.

Simulations of worst-case system throughput were performed using the shuffling pattern of the third example. The following are the main assumptions made for the detailed specification of the simulated system:

Hexagonal 19-cell layout, with a representative segment of the central cell considered for the throughput estimate.
Number of stations **110** (per cell)=12
Static TTI=3 slots (2 ms)
Propagation exponent=3.76
Single path Rayleigh fast fading model (flat spectrum)
Channel conditions stationary during a TTI
MS speed 3 km/h
Standard deviation of log-normal shadowing=8 dB
Shadowing correlation between sites=0.5
30% of BS power allocated to common channels etc in all cells
70% of BS power allocated to HSDPA in all interfering cells
70% of BS power available to HSDPA in wanted cell
Overheads due to dedicated channels associated with HSDPA not considered
10 spreading codes available for HSDPA
MS capability: 5 spreading codes
Spreading factor=16
Available Modulation and Coding Schemes (MCS):
1. QPSK 1/4 rate
2. QPSK 1/2 rate
3. QPSK 3/4 rate
4. 16-QAM 1/2 rate
5. 16-QAM 3/4 rate
Equal transmission power per code
Frame error rate computed from Signal to Interference Ratio (SIR) and block code performance bounds.

To represent streaming services it is assumed that the offered load is comprised of one constant rate data stream per MS **110**. For simplicity equal bit rates are also assumed for each data stream. The data for each user is assumed to arrive at a queue in the BS **100**, and the queue is updated every TTI. It is assumed that one CRC (Cyclic Redundancy Check) is attached per packet.

As a default, Chase combining of re-transmissions is assumed. An erroneous packet is re-transmitted with the same MCS. Perfect maximum ratio combining is assumed, and the final SIR is computed as the sum of the SIRs of the two packets to be combined.

The simulated scheduler is novel, and is intended to maximise system throughputs. This is done by giving priority to the users which can send the largest packets. For the case of a fixed transmission time this is equivalent to scheduling according to the maximum bit rate that can be provided to

each user. The packet size which can be sent is determined mainly by the CIR (Carrier to Interference Ratio). This determines the probability of successful transmission which will be obtained with any given modulation and coding scheme. For each possible scheme an effective packet size can be calculated as $P_{size}=N_{code}\times P_{bits}(1-\text{BLER})$, where N_{code} is the number of channelisation codes which can be used, P_{bits} is the number of bits transmitted per channelisation code, and BLER is the estimated block error rate for the given transmission scheme. N_{code} is most likely to be determined by the capability of of the MS **110** to receive a given number of channelisation codes simultaneously, but it could be limited by the number of codes allocated by the system. There will also be an upper bound on $N_{code}\times P_{bits}$ due to the amount of data in the queue waiting to be sent to that MS.

A viable approach is to calculate the maximum value of P_{size} for each MS **110** at each TTI (sub-frame). Then sort this into a list in order of decreasing P_{size}, then schedule transmission of packets to each MS starting at the front of the list and working down it until all the available downlink resource is assigned. Further variations are possible in which the power assigned to each packet might be adjusted to optimise performance.

Such a scheduler has the aim of maximising total throughput for those stations **110** which have been granted access to HSDPA.

Other general assumptions are that:

A data packet for any user can be allocated to any channelisation code.
More than one channelisation code can be allocated to one user.
The code block size is equal to the amount of data that can be sent with one channelisation code, which means that a "packet" may comprise multiple code blocks sent in parallel within one TTI.
Re-transmissions and first transmissions to the same user are not allowed within the same TTI.
The modulation, coding scheme and power level for first transmissions are chosen to maximise throughput.
All re-transmissions are scheduled before first transmissions, thus giving them a higher priority, and no first transmissions are allowed to a MS **110** while any re-transmissions remain to be sent.
The modulation and coding scheme of a re-transmission is the same as for the first transmission.

The results of the simulation are shown in FIG. **2**, as a graph of system throughput T in millions of bits per second (Mbps) against offered load O in Mbps. Results are shown for three control channel schemes. In the first, shown as a solid line, each MS **110** is allocated a single control channel (and all stations **110** are allocated the same control channel for this worst-case scenario). In the second, shown as a dashed line, an indicator signal is used to inform a MS **110** of which control channel to monitor, hence each MS **110** is effectively monitoring all four channels. In the third, shown as a chain-dashed line, a shuffling control channel allocation is used as shown for the third example above.

The results clearly show that the first scheme can result in significantly degraded performance under worst-case conditions, while the second and third schemes have comparable performance. Although the use of an indicator signal provides the best results, the results from use of a shuffling control allocation scheme are not significantly worse while, as discussed above, providing significant simplifications to system implementation.

In embodiments of the present invention, a range of modifications to the schemes described above are possible. The BS

100 could agree a shuffling pattern with each MS **110**. Then if a MS **110** correctly decodes the control channel for the current TTI, the principle (currently employed in HSDPA) that it decodes the same control channel in the next TTI should be interpreted to mean that in the next TTI the MS **110** decodes the control channel indicated by its assigned shuffling pattern (which may or may not be the same as that for the current TTI).

The time duration of the control channel allocation cycle need not be one frame but could be any convenient length. The timing reference for the shuffling sequence could be a common downlink channel such as a synchronisation channel.

The protocol could be modified so that if a MS **110** detects a control channel transmission but the CRC fails, the MS **110** sends a NACK (negative acknowledgement), which could be different from that sent when the CRC for a data packet fails. This would reduce the power requirements for control channel transmission, since a higher error rate could then be tolerated. This would give the BS **100** some flexibility in choosing the control channel power, but it might restrict the use of non-self-decodable redundancy versions for the re-transmission of data packets (where the original data cannot be deduced from the re-transmission alone).

The transmission of control channels could be restricted in time to one out of every N TTIs (at least for the first packet of a group). This would allow the MS **110** to save some power by not continuously decoding a control channel. The first allocated TTI could be a MS-specific parameter. The restriction could be relaxed when data transmission starts (e.g. when the BS **100** has received an ACK (acknowledgement) for the first packet in a sequence of packets). This event could set a timer. When the timer expires the situation could revert to use of every N^{th} TTI. A range of sequences other than one in every N TTIs could also be used.

There is an alternative method for resolving the scheduling problem where more than one MS **110** needs to be sent data at the same time, but they have been allocated the same control channel. The format of the control channel is modified to contain an indication that a different physical layer message is intended for the MS **110**. In a UMTS embodiment this is preferably as an alternative (rather than an addition) to the information on the format of a data packet to be sent on the downlink data channel. This indication could a single bit flag. The physical layer message in this case would be an instruction to change one or more of the control channel(s) which the MS **110** should monitor, from a among a pre-defined set. In a UMTS embodiment the existing ACK/NACK signalling (currently intended to relate to data on the downlink data channel) could be used to indicate whether the physical layer message was received correctly by the MS **110**. Alternatively different codewords could be used in the ACK/NACK field for this purpose. Some of the existing control channel structure could be used (for example data fields identifying the intended recipient, or CRCs for error detection). Other physical layer messages might be conveyed in the same way, as an alternative to using the control channel to describe the format of a packet on the data channel. This may require a multi-bit indication/flag of message type. Preferably substantially the same format would be used on control channel, irrespective of the message contents.

A further alternative is to add a data field to the control channel so that a message to change the control channel allocation can be sent at the same time as a data packet. This avoids loss of data transmission capacity in the downlink. Such a message could indicate that, starting with a future TTI, the control channel should change. In this case it would be

desirable to limit the size of the message needed (e.g. to one or two bits). Therefore the change could be to a new channel from a small set of available channels or to a new channel which is the next one in a defined sequence.

The description above related to the BS **100** performing a variety of roles relating to the present invention. In practice these tasks may be the responsibility of a variety of parts of the fixed infrastructure, for example in a "Node B", which is the part of the fixed infrastructure directly interfacing with a MS **110**, or at a higher level in the Radio Network Controller (RNC). In this specification, the use of the term "base station" or "primary station" is therefore to be understood to include the parts of the network fixed infrastructure involved in an embodiment of the present invention.

As well as its application in a FDD (Frequency Division Duplex) system as described above, the present invention could be applied in other types of communication system. For example, it could be used in a Time Division Duplex (TDD) system with the modification that the physical channels used may also be distinguished by their use of different time slots or other defined time interval.

The invention claimed is:

1. A radio communication system having a data channel for the transmission of data packets from a primary station to a secondary station and a plurality of control channels for signaling of control information relating to the data packets from the primary station to the secondary station, wherein the primary station comprises means for allocating one of the control channels to the secondary station and means for changing the allocated control channel according to a defined sequence known to both the primary station and the secondary station, and the secondary station comprises means for monitoring the currently allocated control channel to determine information about packet transmissions, wherein the defined sequence is configured to reduce probability of an allocation collision to 1/N, where N is a total number of the control channels.

2. The system as claimed in claim **1**, wherein means are provided for regularly repeating the defined sequence.

3. The system as claimed in claim **2**, wherein the radio channels are divided into time frames and in that means are provided for repeating the defined sequence once per frame.

4. The system as claimed in claim **1**, wherein a timing reference for repetition of the defined sequence is provided by a common downlink channel.

5. The radio communication system of claim **1**, wherein a number of the secondary station is a shuffling pattern identifier, and the secondary station is assigned to a pattern of the defined sequence in an ascending sequence of numbers of secondary stations.

6. The radio communication system of claim **1**, wherein an erroneous packet is re-transmitted before transmission of a new packet.

7. A primary station for use in a radio communication system having a data channel for the transmission of data packets from the primary station to a secondary station and a plurality of control channels for signaling of control information relating to the data packets from the primary station to the secondary station, wherein means are provided for allocating one of the control channels to the secondary station and for changing the allocated control channel according to a defined sequence known to both the primary station and the secondary station, wherein the defined sequence is configured to reduce probability of an allocation collision to 1/N, where N is a total number of the control channels.

8. The primary station as claimed in claim **7**, further comprising means for scheduling data packets for a plurality of secondary stations by giving priority to the largest data packets.

9. The primary station as claimed in claim **7**, further comprising means for allocating control channels for a plurality of secondary stations according to a plurality of respective defined sequences, all of which are different.

10. The primary station as claimed in claim **9**, wherein not all of the defined sequences include more than one control channel.

11. The primary station as claimed in claim **7**, further comprising means for transmitting at least one of the control channels for only a proportion of the time that data packets are transmitted.

12. A secondary station for use in a radio communication system having a data channel for the transmission of data packets from a primary station to the secondary station and a plurality of control channels for signaling of control information relating to the data packets from the primary station to the secondary station, wherein means are provided for determining which of the control channels is allocated to the secondary station, the allocated control channel being changed according to a defined sequence known to both the primary station and the secondary station, and for monitoring the currently allocated control channel to determine information about packet transmissions, wherein the defined sequence is configured to reduce probability of an allocation collision to 1/N, where N is a total number of the control channels.

13. The secondary station as claimed in claim **12**, further comprising means for transmitting a negative acknowledgement to the primary station to indicate that the allocated control channel is successfully detected but cannot be correctly received.

14. The secondary station as claimed in claim **13**, wherein the negative acknowledgement is a different signal from that used to indicate that a data packet could not be correctly received.

15. A method of operating a radio communication system having a data channel for the transmission of data packets from a primary station to a secondary station and a plurality of control channels for signaling of control information relating to the data packets from the primary station to the secondary station, the method comprising acts of:

allocating by the primary station one of the control channels to the secondary station;

changing the allocated control channel according to a defined sequence known to both the primary station and the secondary station; and

monitoring by the secondary station the currently allocated control channel to determine information about packet transmissions, wherein the defined sequence is configured to reduce probability of an allocation collision to 1/N, where N is a total number of the control channels.

16. The method of claim **15**, further comprising the act of assigning the secondary station to a pattern of the defined sequence in an ascending sequence of numbers of secondary stations, wherein a number of the secondary station is a shuffling pattern identifier.

17. The method of claim **15**, further comprising the act re-transmitting an erroneous packet before transmission of a new packet.

* * * * *

EXHIBIT C

US008199711B2

(12) **United States Patent**
Moulsley et al.

(10) **Patent No.: US 8,199,711 B2**
(45) **Date of Patent: *Jun. 12, 2012**

(54) **RADIO COMMUNICATION SYSTEM**

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(73) Assignee: **Koninklijke Philips Electronics N.V.**, Eindhoven (NL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 75 days.

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(63) Continuation of application No. 10/503,429, filed on Aug. 3, 2004, now Pat. No. 7,554,943.

(51) **Int. Cl.**
H04W 4/00 (2009.01)

(52) **U.S. Cl.** **370/329**; 370/341

(58) **Field of Classification Search** 370/329, 370/330, 341, 343, 503; 375/131; 705/9; 455/450, 509

See application file for complete search history.

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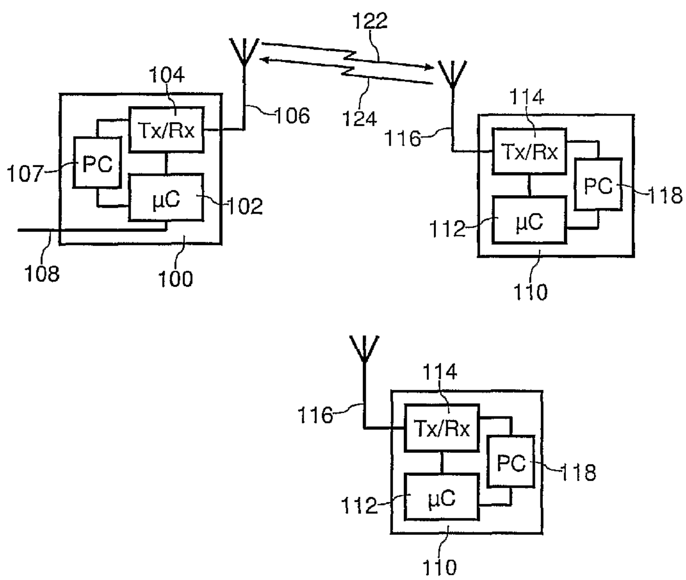
Primary Examiner — Andrew Lai

(57) **ABSTRACT**

In a radio communication system having a data channel for the transmission of data packets from a primary station to a secondary station, a plurality of downlink control channels are used to signal information relating to packet transmission. A problem with this scheme is that with a fixed control channel allocation system throughput (T) for a given offered load (O) can be significantly reduced in a worst case scenario (for example two secondary stations using the same control channel). One solution uses an indicator signal to inform a secondary station of the control channel it should receive, but this adds significant complexity to the system. The present invention provides a simpler scheme having similar benefits by shuffling the allocation of control channels to secondary stations, according to a defined sequence for each secondary station, thereby avoiding the worst case scenario.

12 Claims, 1 Drawing Sheet



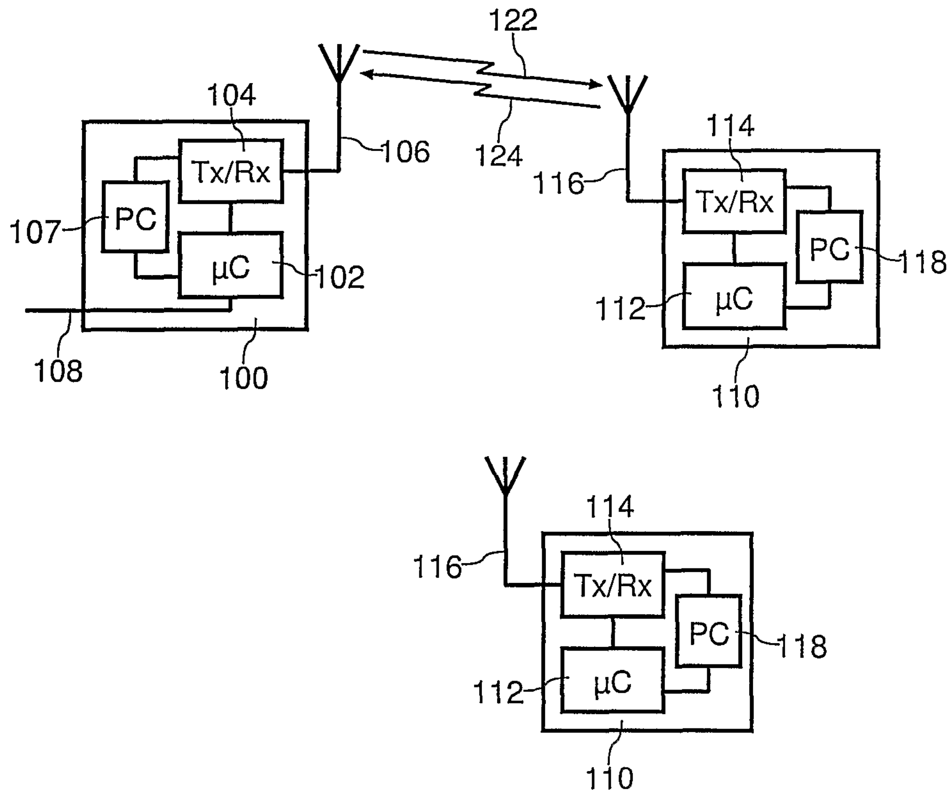

122
104
106
124
114
116
Tx/Rx
PC
107
μC
102
118
112
108
100
110
114
116
Tx/Rx
PC
118
112
μC
110

FIG. 1

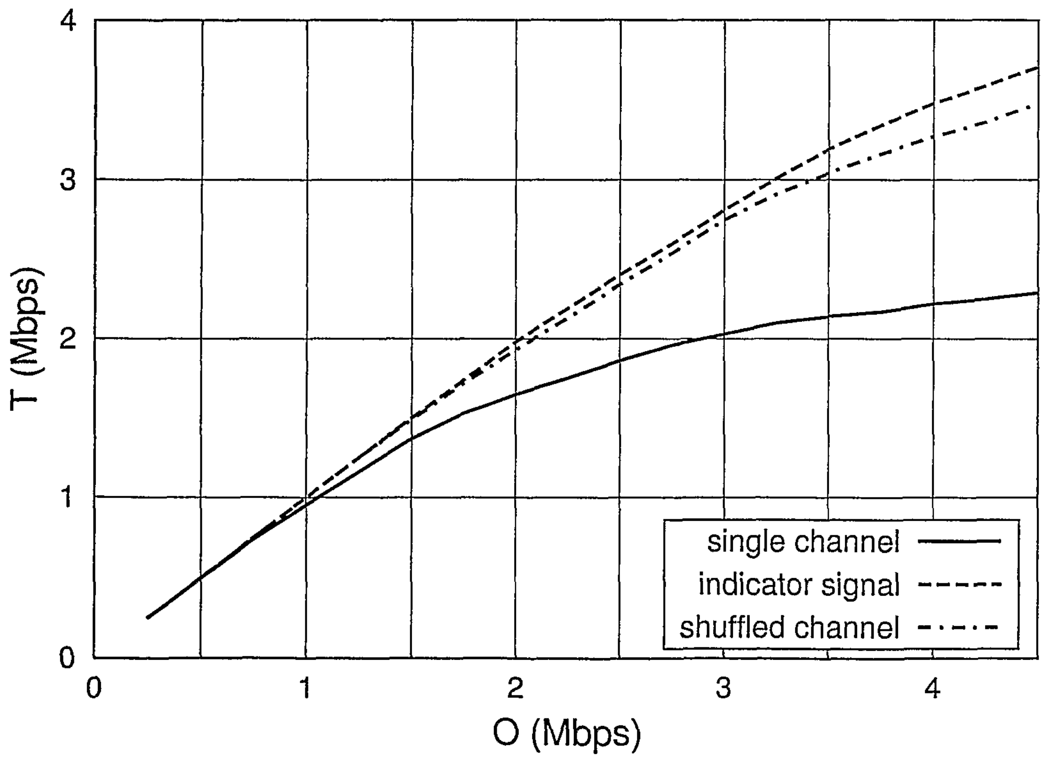

T (Mbps)
O (Mbps)
0
1
2
3
4
single channel
indicator signal
shuffled channel

FIG. 2

RADIO COMMUNICATION SYSTEM

CROSS REFERENCE TO RELATED APPLICATION

This is a continuation application of U.S. patent application Ser. No. 10/503,429 filed Aug. 3, 2004, now U.S. Pat. No. 7,554,943, the contents of which are incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to a radio communication system and further relates to primary and secondary stations for use in such a system and to a method of operating such a system. While the present specification describes a system with particular reference to the Universal Mobile Telecommunication System (UMTS), it is to be understood that such techniques are equally applicable to use in other mobile radio systems.

BACKGROUND ART

There is a growing demand in the mobile communication area for a system having the ability to download large blocks of data to a Mobile Station (MS) on demand at a reasonable rate. Such data could for example be web pages from the Internet, possibly including video clips or similar. Typically a particular MS will only require such data intermittently, so fixed bandwidth dedicated links are not appropriate. To meet this requirement in UMTS, a High-Speed Downlink Packet Access (HSDPA) scheme is being developed which may facilitate transfer of packet data to a mobile station at up to 4 Mbps.

A particular problem with the design of the HSDPA scheme is the mechanism for informing a MS of the presence of a data packet for it to receive and providing information relating to the packet (typically including details of the particular transmission scheme employed, for example spreading code, modulation scheme and coding scheme). As currently proposed, this information is signalled on one of four available downlink control channels, distinguished by their spreading codes. The MS is instructed to decode one of the control channels by a two-bit indicator signal which is transmitted on a low data rate dedicated downlink channel (the signal being inserted by puncturing). The MS then monitors the same control channel for subsequent packets in a burst.

This scheme conveniently supports the scheduling of up to four packets to different MSs in the same time interval. Use of the indicator signal is intended to reduce the complexity of the MS and its power consumption, as the MS only needs to monitor the dedicated downlink channel for the indicator signal instead of having to receive continuously all four control channels. However, there are significant drawbacks with the use of the indicator signal. One drawback is that an additional slot format is required for the dedicated downlink channel (to accommodate the extra signal), which adds complexity. Another drawback is that the transmission power required for the indicator signal can be relatively high to ensure reliable reception of the signal even at the edge of a cell.

One solution which avoids the use of an indicator signal is for each MS to be allocated one of the four control channels, which it then continuously monitors. However, if more than one MS is allocated the same control channel the flexibility of packet scheduling is restricted. Another solution is the provision of one control channel for each MS; however, the potentially large number of channels required could use up excessive system resources.

DISCLOSURE OF INVENTION

An object of the present invention is to provide an improved arrangement which does not require an indicator signal or provision of a large number of control channels.

According to a first aspect of the present invention there is provided a radio communication system having a data channel for the transmission of data packets from a primary station to a secondary station and a plurality of control channels for signalling of control information relating to the data packets from the primary station to the secondary station, wherein the primary station comprises means for allocating one of the control channels to the secondary station and means for changing the allocated control channel according to a defined sequence, and the secondary station comprises means for monitoring the currently allocated control channel to determine information about packet transmissions.

By changing the control channel allocation, system performance is greatly enhanced under worst-case conditions without the need for an indicator signal, which introduces significant extra complexity. The defined sequence may repeat regularly, for example once per frame, and may use as a timing reference a common downlink channel, for example a synchronisation channel in UMTS.

When control channels are allocated to a plurality of secondary stations, their respective defined sequences are preferably all different (provided the number of secondary stations is not too great), and some (but not necessarily all) of the sequences may include only a single control channel.

According to a second aspect of the present invention there is provided a primary station for use in a radio communication system having a data channel for the transmission of data packets from the primary station to a secondary station and a plurality of control channels for signalling of control information relating to the data packets from the primary station to the secondary station, wherein means are provided for allocating one of the control channels to the secondary station and for changing the allocated control channel according to a defined sequence.

According to a third aspect of the present invention there is provided a secondary station for use in a radio communication system having a data channel for the transmission of data packets from a primary station to the secondary station and a plurality of control channels for signalling of control information relating to the data packets from the primary station to the secondary station, wherein means are provided for determining which of the control channels is allocated to the secondary station, the allocated control channel being changed according to a defined sequence, and for monitoring the currently allocated control channel to determine information about packet transmissions.

According to a fourth aspect of the present invention there is provided a method of operating a radio communication system having a data channel for the transmission of data packets from a primary station to a secondary station and a plurality of control channels for signalling of control information relating to the data packets from the primary station to the secondary station, the method comprising the primary station allocating one of the control channels to the secondary station and changing the allocated control channel according to a defined sequence, and the secondary station monitoring

the currently allocated control channel to determine information about packet transmissions.

BRIEF DESCRIPTION OF DRAWINGS

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

FIG. **1** is a block schematic diagram of a radio communication system; and

FIG. **2** is a graph of worst-case system throughput T in millions of bits per second (Mbps) against offered load O in Mbps for various control channel schemes.

MODES FOR CARRYING OUT THE INVENTION

Referring to FIG. **1**, a radio communication system comprises a primary station (BS) **100** and a plurality of secondary stations (MS) **110**. The BS **100** comprises a microcontroller (μC) **102**, transceiver means (Tx/Rx) **104** connected to antenna means **106**, power control means (PC) **107** for altering the transmitted power level, and connection means **108** for connection to the PSTN or other suitable network. Each MS **110** comprises a microcontroller (μC) **112**, transceiver means (Tx/Rx) **114** connected to antenna means **116**, and power control means (PC) **118** for altering the transmitted power level. Communication from BS **100** to MS **110** takes place on a downlink channel **122**, while communication from MS **110** to BS **100** takes place on an uplink channel **124**.

The general characteristics of the UMTS HSDPA were outlined above and are summarised here for clarity:

- There are (low data rate) dedicated uplink **124** and downlink **122** channels between a BS **100** and each MS **110** in its cell.
- A specific downlink channel **122** is used for high-speed transmission of data packets. This channel is subdivided into Transmission Time Intervals (TTIs), where each TTI is the time taken for transmission of a data packet. In UMTS the duration of a TTI is 2 ms, and this time period is also identified as a sub-frame (there being three time slots in a sub-frame, and hence 15 time slots in a 10 ms frame).
- Up to four downlink control channels are provided, distinguished by their spreading codes and each relating to transmission parameters of a data packet. Hence, up to four data packets can be transmitted simultaneously per TTI.
- The requirement for being able to schedule four data packets to different stations **110** in the same TTI is to allow high system throughput to be achieved in a cell in which some stations **110** do not have the ability to receive all of the HSDPA downlink resource. For example, some stations **110** may be able to receive only 5 spreading codes when there are up to 15 available.
- A mechanism is provided for indicating to a particular MS **110** that it is scheduled to receive a data packet and for indicating which control channel it should listen to in order to determine how to receive the packet.

As described above, one possible mechanism is the transmission of an indicator signal on the dedicated downlink channel **122** to inform a MS **110** of the transmission of a data packet. However, this mechanism has a number of problems.

As an alternative each MS **110** could be allocated one of the control channels to monitor, thereby avoiding the need for an indicator signal. However, if more than one MS **110** is allocated to a particular control channel the flexibility of packet scheduling is restricted. For example, consider two mobile stations **110**, each with data to be sent but both allocated the same control channel. It would generally be desirable to send data simultaneously to both stations **110**. However as both stations are sharing a control channel, only one packet can be sent at a time. Given that packet transmission is often bursty in nature, this situation is likely to continue for several TTIs and the system throughput could be only 50% of the maximum. Greater scheduling flexibility could be introduced by requiring each MS **110** to monitor two control channels, but at the cost of increased MS power consumption.

In a system made in accordance with the present invention, this problem is addressed by shuffling the allocation of control channels from one TTI to the next. Hence, if two stations **110** share a control channel in one TTI they will have different ones in the next TTI. If such a scheme is applied to the example above of two active stations **110**, then a well-designed shuffling scheme should be able to reduce the probability of an "allocation collision" to $1/N_{con}$, where N_{con} is the total number of control channels (four in the above examples). The maximum loss in throughput would then be $0.51N_{con}$, or 12.5% with $N_{con}=4$ (compared to 50% without shuffling).

Some examples of how shuffling may be done will now be presented, although the schemes themselves are not necessarily optimal.

First consider the case of two control channels and four stations **110**. The allocation of control channels to each station (0 to 3) for each TTI (0 to 4) in a 10 ms frame is:

	TTI				
station	0	1	2	3	4
0	0	0	0	0	0
1	1	1	1	1	1
2	0	1	0	1	0
3	1	0	1	0	1

This scheme could either repeat in the next frame or be made into a longer cycle.

Next, consider an extension of the above scheme to the case of two control channels and six stations **110**:

	TTI				
station	0	1	2	3	4
0	0	0	0	0	0
1	1	1	1	1	1
2	0	1	0	1	0
3	1	0	1	0	1
4	0	0	1	1	0
5	1	1	0	0	1

As a third example, consider a system with four control channels and twelve stations **110**:

	TTI				
station	0	1	2	3	4
0	0	0	0	0	0
1	1	1	1	1	1
2	2	2	2	2	2
3	3	3	3	3	3

-continued

station	TTI 0	1	2	3	4
4	0	1	2	3	0
5	1	2	3	0	1
6	2	3	0	1	2
7	3	0	1	2	3
8	0	3	2	1	0
9	1	0	3	2	1
10	2	1	0	3	2
11	3	2	1	0	3

It may not be required to have a unique shuffling pattern for each MS **110**. In this case it seems preferable to take the station number as a shuffling pattern identifier, and to assign stations **110** to each pattern in ascending sequence. Hence, for small numbers of stations **110** all (or most) of them will have a constant control channel allocation. Although convenient, it is clearly not a requirement of the present invention that any of the shuffling patterns relate to a constant control channel allocation.

The shuffling pattern of the third example can be represented as

$$n_{CCh}=[(a\Delta n_{TTI})+b] \bmod N_{CCH}$$

where: n_{CCH} is the number of the control channel to be used; N_{CCH} is the total number of control channels available; n_{TTI} is the number of the TTI in the frame; a is a parameter taking values 0, 1 or 3; and b is a parameter taking values 0, 1, 2 or 3.

Simulations of worst-case system throughput were performed using the shuffling pattern of the third example. The following are the main assumptions made for the detailed specification of the simulated system:

Hexagonal 19-cell layout, with a representative segment of the central cell considered for the throughput estimate.
Number of stations **110** (per cell)=12
Static TTI=3 slots (2 ms)
Propagation exponent=3.76
Single path Rayleigh fast fading model (flat spectrum)
Channel conditions stationary during a TTI
MS speed 3 km/h
Standard deviation of log-normal shadowing=8 dB
Shadowing correlation between sites=0.5
30% of BS power allocated to common channels etc in all cells
70% of BS power allocated to HSDPA in all interfering cells
70% of BS power available to HSDPA in wanted cell
Overheads due to dedicated channels associated with HSDPA not considered
10 spreading codes available for HSDPA
MS capability: 5 spreading codes
Spreading factor=16
Available Modulation and Coding Schemes (MCS):
1. QPSK ¼ rate
2. QPSK ½ rate
3. QPSK ¾ rate
4. 16-QAM ½ rate
5. 16-QAM ¾ rate
Equal transmission power per code
Frame error rate computed from Signal to Interference Ratio (SIR) and block code performance bounds

To represent streaming services it is assumed that the offered load is comprised of one constant rate data stream per MS **110**. For simplicity equal bit rates are also assumed for

each data stream. The data for each user is assumed to arrive at a queue in the BS **100**, and the queue is updated every TTI. It is assumed that one CRC (Cyclic Redundancy Check) is attached per packet.

As a default, Chase combining of re-transmissions is assumed. An erroneous packet is re-transmitted with the same MCS. Perfect maximum ratio combining is assumed, and the final SIR is computed as the sum of the SIRs of the two packets to be combined.

The simulated scheduler is novel, and is intended to maximise system throughputs. This is done by giving priority to the users which can send the largest packets. For the case of a fixed transmission time this is equivalent to scheduling according to the maximum bit rate that can be provided to each user. The packet size which can be sent is determined mainly by the CIR (Carrier to Interference Ratio). This determines the probability of successful transmission which will be obtained with any given modulation and coding scheme. For each possible scheme an effective packet size can be calculated as $P_{size}=N_{code}\times P_{bits}(1-\text{BLER})$, where N_{code} is the number of channelisation codes which can be used, P_{bits} is the number of bits transmitted per channelisation code, and BLER is the estimated block error rate for the given transmission scheme. N_{code} is most likely to be determined by the capability of the MS **110** to receive a given number of channelisation codes simultaneously, but it could be limited by the number of codes allocated by the system. There will also be an upper bound on $N_{Code}\times P_{bits}$ due to the amount of data in the queue waiting to be sent to that MS.

A viable approach is to calculate the maximum value of P_{size} for each MS **110** at each TTI (sub-frame). Then sort this into a list in order of decreasing P_{size}, then schedule transmission of packets to each MS starting at the front of the list and working down it until all the available downlink resource is assigned. Further variations are possible in which the power assigned to each packet might be adjusted to optimise performance.

Such a scheduler has the aim of maximising total throughput for those stations **110** which have been granted access to HSDPA.

Other general assumptions are that:
A data packet for any user can be allocated to any channelisation code.
More than one channelisation code can be allocated to one user.
The code block size is equal to the amount of data that can be sent with one channelisation code, which means that a "packet" may comprise multiple code blocks sent in parallel within one TTI.
Re-transmissions and first transmissions to the same user are not allowed within the same TTI.
The modulation, coding scheme and power level for first transmissions are chosen to maximise throughput.
All re-transmissions are scheduled before first transmissions, thus giving them a higher priority, and no first transmissions are allowed to a MS **110** while any re-transmissions remain to be sent.
The modulation and coding scheme of a re-transmission is the same as for the first transmission.

The results of the simulation are shown in FIG. **2**, as a graph of system throughput T in millions of bits per second (Mbps) against offered load in Mbps. Results are shown for three control channel schemes. In the first, shown as a solid line, each MS **110** is allocated a single control channel (and all stations **110** are allocated the same control channel for this worst-case scenario). In the second, shown as a dashed line, an indicator signal is used to inform a MS **110** of which

control channel to monitor, hence each MS **110** is effectively monitoring all four channels. In the third, shown as a chain-dashed line, a shuffling control channel allocation is used as shown for the third example above.

The results clearly show that the first scheme can result in significantly degraded performance under worst-case conditions, while the second and third schemes have comparable performance. Although the use of an indicator signal provides the best results, the results from use of a shuffling control allocation scheme are not significantly worse while, as discussed above, providing significant simplifications to system implementation.

In embodiments of the present invention, a range of modifications to the schemes described above are possible. The BS **100** could agree a shuffling pattern with each MS **110**. Then if a MS **110** correctly decodes the control channel for the current TTI, the principle (currently employed in HSDPA) that it decodes the same control channel in the next TTI should be interpreted to mean that in the next TTI the MS **110** decodes the control channel indicated by its assigned shuffling pattern (which may or may not be the same as that for the current TTI).

The time duration of the control channel allocation cycle need not be one frame but could be any convenient length. The timing reference for the shuffling sequence could be a common downlink channel such as a synchronisation channel.

The protocol could be modified so that if a MS **110** detects a control channel transmission but the CRC fails, the MS **110** sends a NACK (negative acknowledgement), which could be different from that sent when the CRC for a data packet fails. This would reduce the power requirements for control channel transmission, since a higher error rate could then be tolerated. This would give the BS **100** some flexibility in choosing the control channel power, but it might restrict the use of non-self-decodable redundancy versions for the re-transmission of data packets (where the original data cannot be deduced from the re-transmission alone).

The transmission of control channels could be restricted in time to one out of every N TTIs (at least for the first packet of a group). This would allow the MS **110** to save some power by not continuously decoding a control channel. The first allocated TTI could be a MS-specific parameter. The restriction could be relaxed when data transmission starts (e.g. when the BS **100** has received an ACK (acknowledgement) for the first packet in a sequence of packets). This event could set a timer. When the timer expires the situation could revert to use of every N^{th} TTI. A range of sequences other than one in every N TTIs could also be used.

There is an alternative method for resolving the scheduling problem where more than one MS **110** needs to be sent data at the same time, but they have been allocated the same control channel. The format of the control channel is modified to contain an indication that a different physical layer message is intended for the MS **110**. In a UMTS embodiment this is preferably as an alternative (rather than an addition) to the information on the format of a data packet to be sent on the downlink data channel. This indication could a single bit flag. The physical layer message in this case would be an instruction to change one or more of the control channel(s) which the MS **110** should monitor, from a among a pre-defined set. In a UMTS embodiment the existing ACK/NACK signalling (currently intended to relate to data on the downlink data channel) could be used to indicate whether the physical layer message was received correctly by the MS **110**. Alternatively different codewords could be used in the ACK/NACK field for this purpose. Some of the existing control channel structure could be used (for example data fields identifying the intended recipient, or CRCs for error detection). Other physical layer messages might be conveyed in the same way, as an alternative to using the control channel to describe the format of a packet on the data channel. This may require a multi-bit indication/flag of message type. Preferably substantially the same format would be used on control channel, irrespective of the message contents.

A further alternative is to add a data field to the control channel so that a message to change the control channel allocation can be sent at the same time as a data packet. This avoids loss of data transmission capacity in the downlink. Such a message could indicate that, starting with a future TTI, the control channel should change. In this case it would be desirable to limit the size of the message needed (e.g. to one or two bits). Therefore the change could be to a new channel from a small set of available channels or to a new channel which is the next one in a defined sequence.

The description above related to the BS **100** performing a variety of roles relating to the present invention. In practice these tasks may be the responsibility of a variety of parts of the fixed infrastructure, for example in a “Node B”, which is the part of the fixed infrastructure directly interfacing with a MS **110**, or at a higher level in the Radio Network Controller (RNC). In this specification, the use of the term “base station” or “primary station” is therefore to be understood to include the parts of the network fixed infrastructure involved in an embodiment of the present invention.

As well as its application in a FDD (Frequency Division Duplex) system as described above, the present invention could be applied in other types of communication system. For example, it could be used in a Time Division Duplex (TDD) system with the modification that the physical channels used may also be distinguished by their use of different time slots or other defined time interval.

The invention claimed is:

1. A radio communication system having a data channel for the transmission of data packets from a primary station to a secondary station and a plurality of control channels for signaling of control information relating to the data packets from the primary station to the secondary station, wherein the primary station comprises means for allocating one of the control channels to the secondary station and means for changing the allocated control channel according to a defined sequence, and the secondary station comprises means for monitoring the currently allocated control channel to determine information about packet transmissions, and wherein the primary station comprises means for allocating control channels for a plurality of secondary stations according to a plurality of respective defined sequences, all of which are different.

2. The system as claimed in claim **1**, wherein means are provided for repeating the defined sequence.

3. The system as claimed in claim **1**, wherein the radio channels are divided into time frames and wherein means are provided for repeating the defined sequence once per frame.

4. The system as claimed in claim **1**, wherein a timing reference for repetition of the defined sequence is provided by a common downlink channel.

5. A primary station for use in a radio communication system having a data channel for the transmission of data packets from the primary station to a secondary station and a plurality of control channels for signaling of control information relating to the data packets from the primary station to the secondary station, wherein means are provided for allocating

one of the control channels to the secondary station and for changing the allocated control channel according to a defined sequence,

wherein means are provided for allocating control channels for a plurality of secondary stations according to a plurality of respective defined sequences, all of which are different.

6. The primary station as claimed in claim **5**, wherein means are provided for scheduling data packets for a plurality of secondary stations by giving priority to the largest data packets.

7. The primary station as claimed in claim **5**, wherein not all of the defined sequences include more than one control channel.

8. The primary station as claimed in claim **5**, wherein means are provided for transmitting at least one of the control channels for only a proportion of the time that data packets are transmitted.

9. A secondary station for use in a radio communication system having a data channel for the transmission of data packets from a primary station to the secondary station and a plurality of control channels for signaling of control information relating to the data packets from the primary station to the secondary station, wherein means are provided for determining which of the control channels is allocated to the secondary station wherein the control channels are allocated for a plurality of secondary stations according to a plurality of respective defined sequences, all of which are different, the allocated control channel being changed according to a respective defined sequence, and for monitoring the currently allocated control channel to determine information about packet transmissions.

10. The secondary station as claimed in claim **9**, wherein means are provided for transmitting a negative acknowledgement to the primary station to indicate that the allocated control channel is successfully detected but cannot be correctly received.

11. The secondary station as claimed in claim **10**, wherein the negative acknowledgement is a different signal from that used to indicate that a data packet could not be correctly received.

12. A method of operating a radio communication system having a data channel for the transmission of data packets from a primary station to a secondary station and a plurality of control channels for signaling of control information relating to the data packets from the primary station to the secondary station, the method comprising the primary station allocating one of the control channels to the secondary station and changing the allocated control channel according to a defined sequence, and the secondary station monitoring the currently allocated control channel to determine information about packet transmissions,

wherein the primary station allocates control channels for a plurality of secondary stations according to a plurality of respective defined sequences, all of which are different.

* * * * *

EXHIBIT D

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Baker et al.

(10) **Patent No.: US 7,831,271 B2**
(45) **Date of Patent: Nov. 9, 2010**

(54) **COMMUNICATION SYSTEM AND METHOD OF OPERATING THE COMMUNICATING SYSTEM**

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(73) Assignee: **Koninklijke Philips Electronics N.V.**, Eindhoven (NL)

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(2), (4) Date: **Feb. 2, 2006**

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PCT Pub. Date: **Feb. 17, 2005**

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H04B 7/00 (2006.01)

(52) **U.S. Cl.** **455/522**; 455/69; 370/318

(58) **Field of Classification Search** 455/522, 455/69; 370/318, 335, 329
See application file for complete search history.

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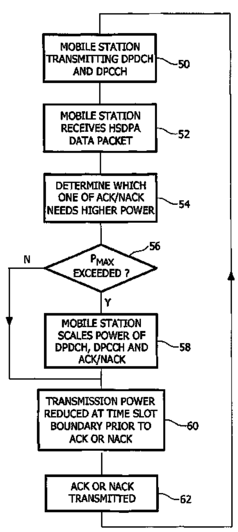
Primary Examiner—Nay A Maung
Assistant Examiner—Angelica M Perez

(57) **ABSTRACT**

A communication system, for example UMTS (Universal Mobile Telecommunication System), comprises a base station and a plurality of mobile stations. In normal operation the mobile station continuously makes uplink transmissions on certain spread spectrum channels (DPDCH, DPCCH). The maximum allowed power (Pmax) for these uplink transmissions is specified. However there are occasions when for example receiving packet data from the base station, the receiving mobile station has to transmit an acknowledgement (ACK) or a Non-acknowledgement (NACK) at a power level specified by the base station. In order to keep the transmit power of the mobile station within the maximum allowed power, the total power required to transmit an ACK or NACK in parallel with the continuous uplink signals is determined and if this exceeds Pmax then at least the power DPDCH and DPCCH channels are scaled to allow sufficient power for the transmission of an ACK or NACK. The power scaling is carried-out based on the power required for whichever one of ACK or NACK requires the most power. This avoids reducing the amount of time available to a mobile whether an ACK or NACK should be transmitted.

9 Claims, 3 Drawing Sheets



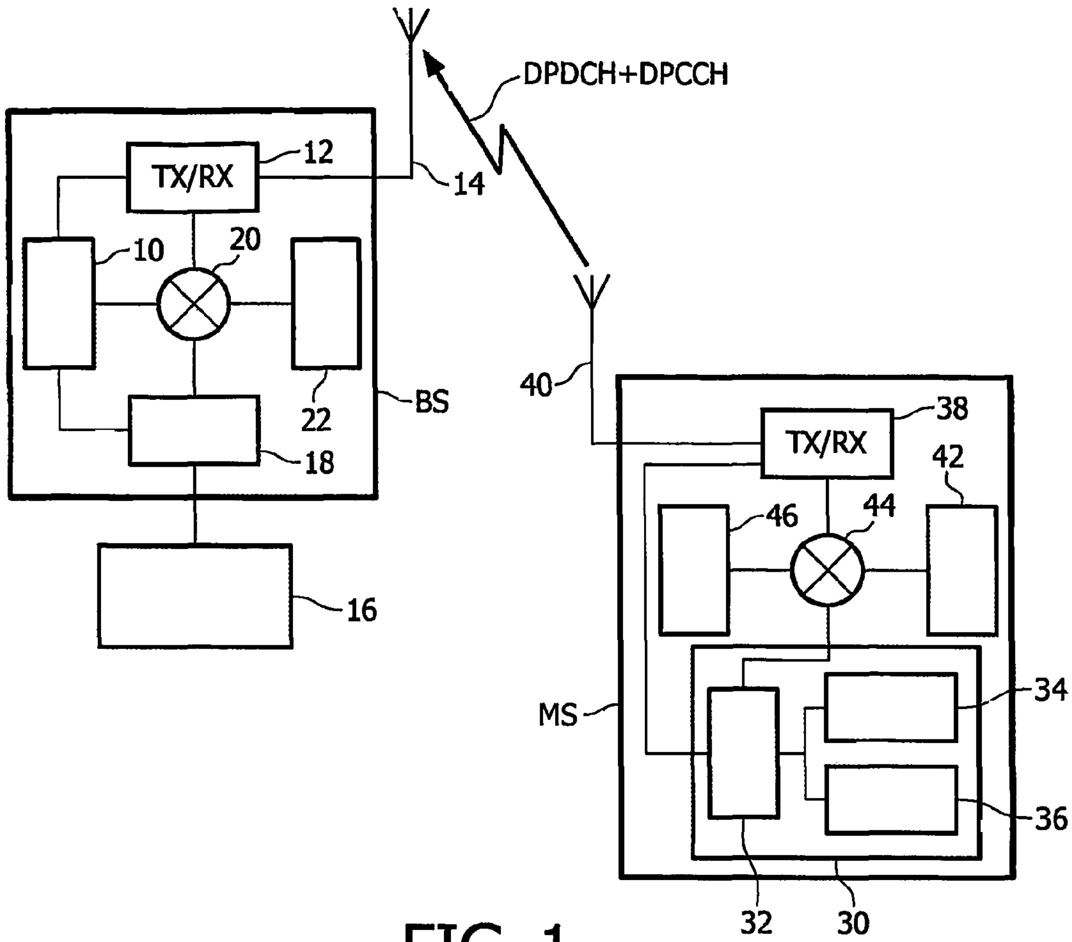

DPDCH+DPCCH
TX/RX
12
14
10
20
22
BS
18
16
40
TX/RX
38
42
46
44
MS
34
36
32
30

FIG. 1

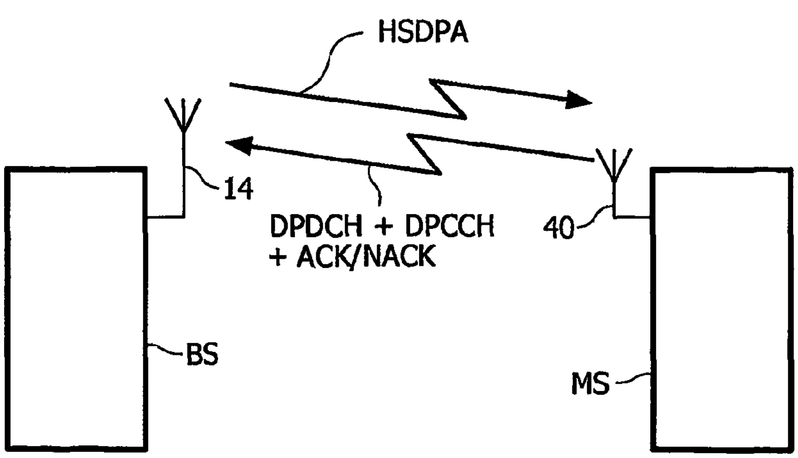
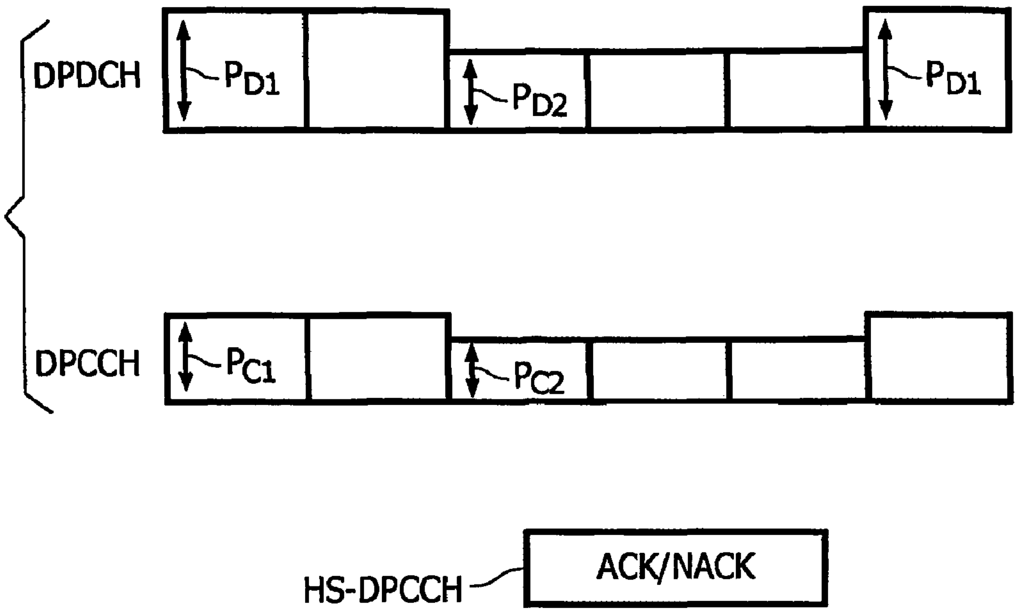
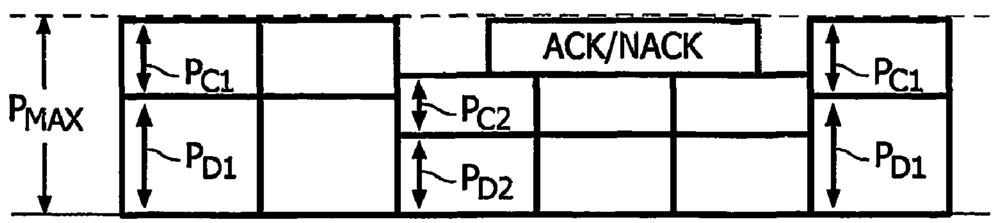

HSDPA
14
DPDCH + DPCCH
+ ACK/NACK
40
BS
MS

FIG. 2



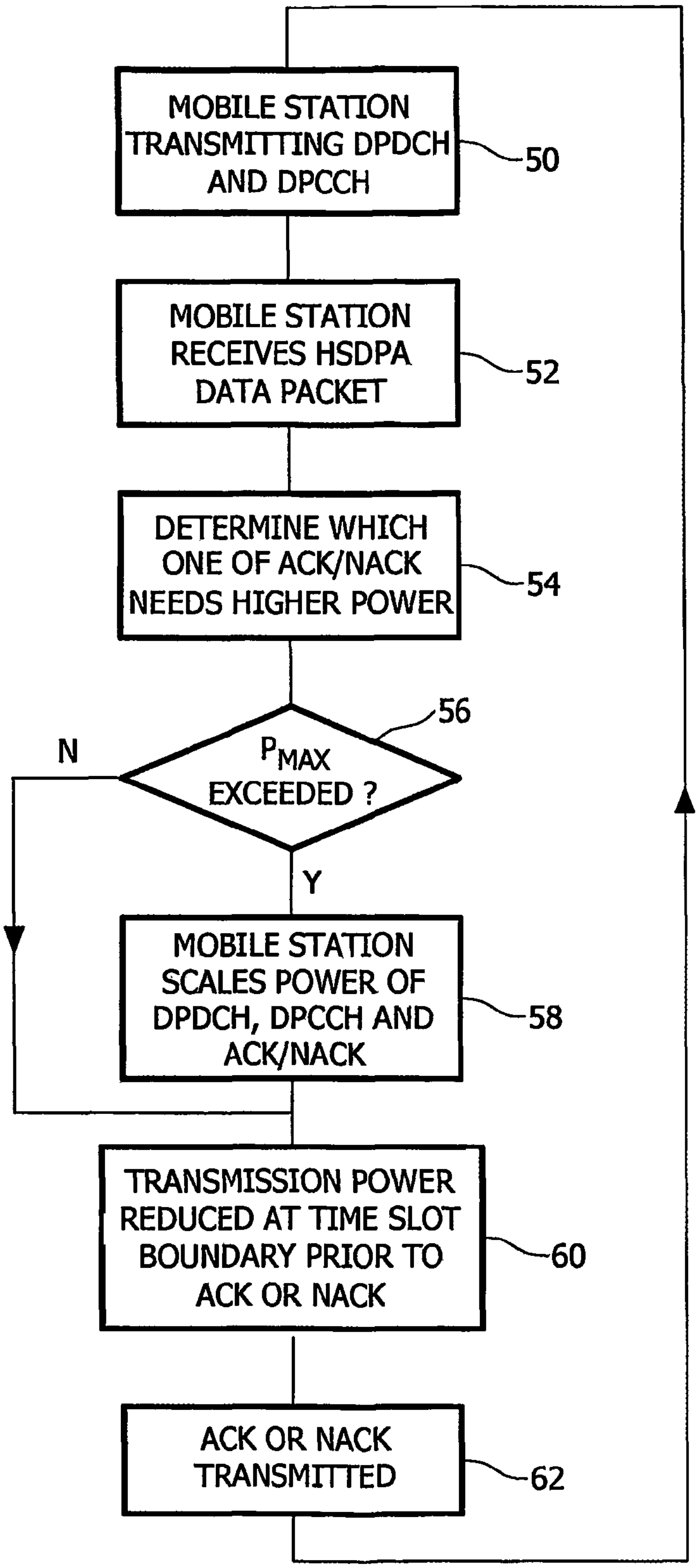
DPDCH
PD1
PD2
PD1
DPCCH
PC1
PC2
HS-DPCCH
ACK/NACK

FIG. 3



PMAX
PC1
PD1
ACK/NACK
PC2
PD2
PC1
PD1

FIG. 4



MOBILE STATION TRANSMITTING DPDCH AND DPCCH
50
MOBILE STATION RECEIVES HSDPA DATA PACKET
52
DETERMINE WHICH ONE OF ACK/NACK NEEDS HIGHER POWER
54
56
N
P_{MAX} EXCEEDED ?
Y
MOBILE STATION SCALES POWER OF DPDCH, DPCCH AND ACK/NACK
58
TRANSMISSION POWER REDUCED AT TIME SLOT BOUNDARY PRIOR TO ACK OR NACK
60
ACK OR NACK TRANSMITTED
62

FIG. 5

COMMUNICATION SYSTEM AND METHOD OF OPERATING THE COMMUNICATING SYSTEM

The present invention relates to a communication system, to a station for use in a communication system, and to a method of operating a communication system. The present invention has particular, but not exclusive, application to spread spectrum systems such as UMTS (Universal Mobile Telecommunication System).

Terminals in mobile communication systems usually have a maximum transmit power limit, which may be set by physical constraints or in response to an instruction received from a controller.

In a communication system while a terminal is transmitting a first signal, it is sometimes necessary to transmit simultaneously additional signals which would require the terminal's maximum transmit power limit to be exceeded. In such cases, a variety of approaches may be taken, including reducing the transmit power of the first signal in order to allow sufficient power for the additional signal(s) to be transmitted without breaching the maximum power limit or switching-off part or all of the first signal in order to allow the additional signal(s) to be transmitted.

In some systems, it is only possible to execute the reduction in transmit power of the first signal at particular time instants, such as a frame- or timeslot-boundary. These time instants may not correspond to the times at which the transmission of the additional signal(s) must commence. A method of overcoming this problem is to execute a reduction in transmit power in advance of the transmission of the additional signal(s).

In such situations, the exact nature of the additional signal(s) may not yet be known at the time when the reduction in transmit power of the first signal has to be executed because, for example, there is insufficient time for the terminal to evaluate a critical feature, such as a CRC (cyclic redundancy check) in a received signal. Different types of additional signal may have different transmit power requirements.

An object of the present invention is to be able to transmit an additional signal in a timely manner whilst not exceeding a predetermined maximum power limit.

According to a first aspect of the present invention there is provided a method of operating a communication system comprising a first station and a second station, the first and second stations each having transceiving means, the second station transmitting a first signal to the first station, the power of the transmitted first signal not exceeding a predetermined maximum level, wherein in response to the second station wishing to transmit any one of a set of possible additional signals, the transmit power of the first signal is scaled by an amount which takes into account the greater (or greatest) power requirement of all of the set of the possible additional signals to be transmitted subsequently.

According to a second aspect of the present invention there is provided a communication system comprising a first station and a second station, the first station and second stations having transceiving means, the second station having power control means for controlling the transmitted power level of a first signal to be transmitted to the first station, wherein the power control means is adapted, in response to determining that the second station wishes to transmit any one of a set of possible additional signals simultaneously with the first signals, to scale the transmit power of the first signal by an amount which takes into account the greater (or greatest) power requirement of all of the set of the possible additional signals to be transmitted subsequently.

According to a third aspect of the present invention there is provided a second station for use in a communication system comprising a first station and a second station, the second station including transceiving means for communication with the first station, and power control means for controlling the transmitted power level of a first signal to be transmitted to the first station, wherein the power control means is adapted, in response to determining that the second station wishes to transmit any one of a set of possible additional signals simultaneously with the first signals, to scale the transmit power of the first signal by an amount which takes into account the greater (or greatest) power requirement of all of the set of the possible additional signals to be transmitted subsequently.

The method in accordance with the present invention avoids setting a requirement on the terminal to make an earlier decision about which type of additional signal is to be transmitted, or to make a reduction in power of the first signal at some time other than the most convenient or required instant.

The present invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

FIG. **1** is a block schematic diagram of an UMTS communication system,

FIG. **2** is a simplified block schematic diagram illustrating the downlink and uplink signals,

FIG. **3** is a timing diagram showing individually the uplink signals,

FIG. **4** is a timing diagram showing the combination of the uplink signals, and

FIG. **5** is a flow chart illustrating an embodiment of the method in accordance with the present invention.

In the drawings the same reference numbers have been used to indicate corresponding features.

The UMTS communication system comprises at least one base station BS and a plurality of mobile stations MS, one of which is shown in FIG. **1**. The mobile stations are able to roam within the radio coverage of the base station(s) and maintain radio communication by way of spread spectrum signalling on downlinks from the base station(s) and uplinks from the mobile stations. As is customary with spread spectrum signalling several signals can be transmitted simultaneously each signal having its own signature or spreading code selected from a set of signatures. Additionally power control has to be effected to prevent weaker signals being swamped by more powerful signals. Accordingly a base station can specify the maximum power at which a mobile station can transmit on the uplink.

Referring to FIG. **1**, the base station BS is controlled by a controller **10** which carries out the many functions involved in the maintenance of the system and the sending and receiving of signals. A transceiver **12** is coupled to an antenna **14** for the transmission and reception of spread spectrum signals. An external source of data **16** is coupled to a base band stage **18** in which data is formatted into packets. The data packets are prepared for transmission by multiplying them in a multiplier **20** with a signature, for example a pseudo random code, obtained from a code store **22** under the control of the controller **10**. The spread spectrum signal is passed to the transceiver for modulation and transmission.

In the case of a signal received at the antenna it is demodulated and despread by multiplying the demodulated signal with the appropriate signature. Thereafter the despread signal is passed to the base band stage **18**.

The mobile station MS is controlled by a controller **30** which carries out the many functions involved in the operation of the mobile station, including the sending and receiving of signals. For convenience of illustration and to facilitate an

understanding of the present invention the controller **30** is shown as comprising a microprocessor **32**, a transmit power controller **34** and a power scaler **36**. A transceiver **38** is coupled to an antenna **40** for the transmission and reception of spread spectrum signals from the base station BS. A man/machine interface **42**, which includes a base band data formatting and deformatting stage, means for inputting data and means for outputting data, is coupled to a multiplier **44** to which is supplied a signature, for example a pseudo random code, obtained from a code store **46** under the control of the microprocessor **32**. A signal to be transmitted on the uplink is spread and is passed to the transceiver **38** for modulation and transmission.

In the case of a downlink signal received at the antenna **40** it is demodulated and despread by multiplying the demodulated signal with the appropriate signature. Thereafter the despread signal is passed to the man/machine interface **42**.

In the case of UMTS the operating standard requires each mobile station to transmit spread spectrum uplink signals substantially continuously. These signals are formatted into successive frames or time slots whose duration is specified by the system. Two signals are often transmitted continuously and these are a dedicated physical data channel DPDCH and dedicated physical control channel DPCCH, these signals are shown in FIG. **1**. Only DPCCH is transmitted when there is no data. The relative transmission power levels P_D and P_C of the DPDCH and DPCCH channels are regulated so as to maintain a fixed power ratio for a given data type and their combined powers are controlled so as not to exceed an allowable maximum power level P_{max}. Further while maintaining the fixed power ratio, the power level P_C of the DPCCH is adjusted periodically by a closed-loop power control mechanism.

Referring to FIG. **2**, which is a simplified version of FIG. **1**, from time to time the base station BS uses the downlink to transmit packet data to an identified mobile station using High-Speed Downlink Packet Access HSDPA. Under the UMTS standard, the mobile station MS must transmit a positive (ACK) or negative (NACK) acknowledgement for each HSDPA packet received, depending for example on the outcome of a cyclic redundancy check (CRC) evaluation.

Referring to FIG. **3** the ACKs and NACKs are transmitted as spread spectrum signals on a so-called High-Speed Dedicated Physical Control Channel (HS-DPCCH), whose time slots are not aligned with the time slots on the other uplink channels carrying the continuous uplink signals DPDCH and DPCCH. The relative transmit powers of the ACKs and NACKs are different and the respective transmit powers are determined by the base station BS and notified to the mobile station MS.

If the transmission of an ACK or NACK in parallel with the continuous uplink signals would require more transmit power than is allowed, the transmit power must be reduced. If the adjustment of the respective signal powers is delayed until the CRC in the HSDPA packet is evaluated, in the case of a large packet it would be difficult, if not impossible, to make the adjustment at a DPCCH slot boundary as specified in the UMTS standard.

To avoid this problem the method in accordance with the present invention causes the transmit power of the other uplink channels, that is, the DPDCH and DPCCH, to be reduced at the timeslot boundary immediately preceding the start of the ACK or NACK transmission. However, as mentioned above, the transmit power for ACKs is required to be different from the transmit power for NACKs. Consequently, if the mobile station MS was to know by how much to reduce the power of the continuous signals DPDCH and DPCCH in time for the slot boundary prior to the start of the ACK or NACK transmission, it would need to complete the CRC evaluation process more quickly than the time allowed by the timing of the ACK/NACK transmission. Since this is not possible, the mobile station MS reduces the transmit power at the time slot prior to the start of the ACK/NACK transmission by an amount corresponding to whichever of ACK or NACK has the higher power requirement P_A or P_N, respectively. In this way, the mobile station MS can ensure that enough transmit power is available for the ACK/NACK transmission regardless of the final outcome of the CRC evaluation process.

The principle is illustrated in FIGS. **3** and **4**. In FIG. **3** the mobile station MS is initially transmitting at its maximum allowed power, $P_{max}=P_{C1}+P_{D1}$.

Suppose that P_A is defined to be $2P_C$ and P_N is defined to be equal to P_C.

Then the powers of the DPDCH and DPCCH must be reduced to P_{D2} and P_{C2}, respectively, such that

$$P_{C2}+P_{D2}+P_A=P_{max}$$

That is, $P_{C2}+P_{D2}+2P_{C2}=P_{max}$.

The power ratio between the control and data channels is maintained, such that $P_{D2}/P_{C2}=P_{D1}/P_{C1}$.

$$\text{Thus } P_{C2}=\frac{P_{C1}+P_{D1}-P_A}{1+P_{D1}/P_{C1}} \text{ or } P_{C2}=\frac{P_{C1}+P_{D1}}{3+P_{D1}/P_{C1}}$$

$$\text{and } P_{D2}=\frac{P_{C1}+P_{D1}-P_A}{1+P_{C1}/P_{D1}} \text{ or } P_{D2}=\frac{P_{C1}+P_{D1}}{1+3P_{C1}/P_{D1}}.$$

In FIG. **4** the broken horizontal line illustrates the maximum allowed transmit power P_{max}. When there is not ACK or NACK to be transmitted then the combined maximum amplitudes of P_{D1} and P_{C1} equal P_{max}. However at the boundary of the frame or time slot immediately preceding the sending of an ACK or NACK, these amplitudes are adjusted by for example reducing DPCCH whilst maintaining the power ratio P_D/P_C constant. Thus capacity is left for the transmission of the higher power one of ACK or NACK, even though the lower power one may be transmitted thereby making the combined transmit power lower than P_{max}.

The flow chart shown in FIG. **5** summarises the operations carried out by the secondary station in implementing the method in accordance with the present invention. Block **50** relates to the mobile station MS continuously transmitting the DPDCH and DPCCH signals at a combined transmit power level equal to or less than the maximum allowable power level P_{max}. Block **52** relates to the mobile station receiving packet data in a downlink HSDPA packet data signal. Block **54** denotes the mobile station determining the power levels for the ACK or NACK signal and the greater one of the two levels. Block **56** denotes checking if P_{max} would be exceeded by an uplink signal comprising DPDCH, DPCCH and the higher power of the ACK or NACK signals. If the answer is yes (Y) then in block **58** the scaling stage **36** (FIG. **1**) of the mobile station scales the power of at least the DPCCH channel so that P_{max} will not be exceeded. The flow chart proceeds to block **60**. If the answer in the block **56** is no (N) the flow chart proceeds to the block **60**. The block **60** denotes the power control stage **34** (FIG. **1**) of the mobile station reducing the power of the DPDCH and DPCCH channels at the frame or time slot boundary preceding the transmission of the ACK or NACK. Block **62** relates to the mobile station MS transmitting the ACK or NACK.

When implementing the method in accordance with the present invention the scaling of the DPCCH power may coincide with a requested power increase, for example due to a closed loop power control process or a change in data format on the DPDCH. In this case, the result of the scaling process in accordance with the present invention may in fact be to increase the DPCCH (+DPDCH) transmit power, but by a smaller amount than was requested by the closed loop power control process and/or change in DPDCH data format. This situation may arise where the sum of P_{C1} and P_{D1} is less than P_{max}, but the sum of P_{C2}+P_{D2}+ the greater of P_A and P_N would be greater than P_{max} if the scaling were not applied.

In another embodiment, the additional signals may carry information other than ACK/NACK signalling; for example, they may carry packet data (as in the proposed enhanced uplink in UMTS) or other signalling information.

In a further non-illustrated embodiment the base station may be required to implement the method in accordance with the present invention rather than the mobile station.

Although the method in accordance with the present invention has been described with reference to a spread spectrum communication system, its teachings may be applied to other systems having transmitter power control.

In the present specification and claims the word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. Further, the word "comprising" does not exclude the presence of other elements or steps than those listed.

From reading the present disclosure, other modifications will be apparent to persons skilled in the art. Such modifications may involve other features which are already known in the design, manufacture and use of telecommunication systems and component parts therefor and which may be used instead of or in addition to features already described herein.

The invention claimed is:

1. A method of operating a communication station (MS) adapted to transmit a plurality of signals simultaneously at respective power levels, the method comprising:

transmitting one or more first signals (DPCCH, DPDCH) simultaneously at a specified maximum combined transmit power level (P_{max});

wherein, in response to a received signal, reducing the transmit power of the one or more first signals (DPCCH, DPDCH) and transmitting simultaneously with the one or more first signals (DPCCH, DPDCH) an additional one of a second signal (ACK or NACK) at a respective second specified power level (P_A or P_N) and a third signal (NACK or ACK) at a respective third specified power level (P_N or P_A), wherein the second specified power level (P_A or P_N) exceeds the third specified power level (P_N or P_A); wherein the reduction in transmit power of the one or more first signals (DPCCH, DPDCH) corresponds to the second specified power level (P_A or P_N) irrespective of whether the additional signal is the second signal (ACK or NACK) or the third signal (NACK or ACK), such that when the additional signal is the third signal (NACK or ACK) the combined transmit power level is less than the specified maximum combined transmit power level (P_{max}).

2. A method of operating a communication station (MS) as claimed in claim **1** wherein the one or more first signals (DPCCH, DPDCH) are transmitted in first frames or time slots and the additional signals are transmitted in second frames or time slots, wherein the boundaries between the first frames or time slots are not coincident with the boundaries between the second frames or time slots, wherein the reduction in transmit power of the one or more first signals (DPCCH, DPDCH) commences at the first frame or time slot boundary immediately preceding the transmission of the additional signal.

3. A method of operating a communication station (MS) as claimed in claim **1**, wherein the second signal (ACK or NACK) is a positive acknowledgement and the third signal (NACK or ACK) is a negative acknowledgement.

4. A method of operating a communication station (MS) as claimed in claim **1**, wherein the signals are spread spectrum signals.

5. A communication station (MS) adapted to transmit a plurality of signals simultaneously at respective power levels, comprising:

transceiver means (**38**) for transmitting one or more first signals (DPCCH, DPDCH) simultaneously at a specified maximum combined transmit power level (P_{max}), for receiving signals, and for, in response to a received signal, transmitting simultaneously with the one or more first signals (DPCCH, DPDCH) an additional one of a second signal (ACK or NACK) and a third signal (NACK or ACK);

control means (**30**) for controlling the transmitted power level of the one or more first signals (DPCCH, DPDCH) and the additional signal (ACK, NACK);

wherein the control means (**34**) is adapted to, in response to the received signal, reduce the transmit power of the one or more first signals (DPCCH, DPDCH) and to set the transmit power of the additional signal, if the additional signal is the second signal (ACK or NACK), to a respective second specified power level (P_A or P_N) and, if the additional signal is the third signal (NACK or ACK), to a respective third specified power level (P_N or P_A), wherein the second specified power level (P_A or P_N) exceeds the third specified power level (P_N or P_A); wherein the reduction in transmit power of the one or more first signals (DPCCH, DPDCH) corresponds to the second specified power level (P_A or P_A) irrespective of whether the additional signal is the second signal (ACK or NACK) or the third signal (NACK or ACK), such that when the additional signal is the third signal (NACK or ACK) the combined transmit power level is less than the specified maximum combined transmit power (Pmax).

6. A communication station (MS) as claimed in claim **5** wherein the control means (**34**) is adapted to transmit the one or more first signals (DPCCH, DPDCH) in first frames or time slots and to transmit the additional signals in second frames or time slots, wherein the boundaries between the first frames or time slots are not coincident with the boundaries between the second frames or time slots, wherein the reduction in transmit power of the one or more first signals (DPCCH, DPDCH) commences at the first frame or time slot boundary immediately preceding the transmission of the additional signal.

7. A communication station (MS) as claimed in claim **5** wherein the second signal (ACK or NACK) is a positive acknowledgement and the third signal (NACK or ACK) is a negative acknowledgement.

8. A communication station (MS) as claimed in claim **5** wherein the signals are spread spectrum signals.

9. A communication system comprising a communication station (MS) as claimed in claim **5** and another station (BS) having a transceiver for communication with the communication station (MS).

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